Applying the New Zealand Performance Based Design Fire Framework to Buildings Designed in Accordance with NFPA5000

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Abstract

A framework for performance based fire design is in the process of being developed by the Department of Building and Housing and such a framework may become a compulsory methodology for performance based fire design in the future. The framework has been developed with the intention of providing a similar level of safety to a building as if the building is designed in accordance with the New Zealand compliance document C/AS1. Ten design fire scenarios have been included in the framework to ensure buildings will be challenged. Design fires for particular building uses, tenability criteria for occupant safety, detector criteria to determine detection time and pre-movement time for egress calculation have been specified in the framework.

In order to provide a comparison of the framework against the international building code, three complex case studies have been applied to buildings designed in accordance with NFPA5000 and investigated using the input values and methodologies described in the framework. The case study buildings selected are a retail warehouse, a hospital and a shopping mall. The selection of the buildings was based on complexity of building layout, likelihood of rapid fire growth and high occupancy.

Zone modelling (BRANZFIRE modelling) and Computational Fluid Dynamics (Fire Dynamic Simulation modelling) have been utilised in an Available Safe Egress Time (ASET) and Required Safe Egress Time (RSET) analysis. Results of the research showed that the framework provided a robust and consistent method for performance based fire design and the guidance provided in the framework gave a clear methodology to determine the ASET and the RSET. In additional, the framework provided an even more restrictive requirement than the prescriptive requirement in the NFPA5000 in relation to external walls fire resistance and mezzanine floor fire resistance. Conversely, it provided a too relaxed requirement than the prescriptive requirement in the NFPA5000 in relation to means of egress and fire/smoke compartmentation.

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Glossary

The following definitions apply in this research which are based on the actual wording of the framework [1], C/AS1 [2] and NFPA5000 [3].

Area of Refuge [3]

An area that is either (1) a story in a building where the building is protected throughout by an approved, supervised automatic sprinkler system and has not less than two accessible rooms or spaces separated from each other by smoke-resisting partitions; or (2) a space located in a path of travel leading to a public way that is protected from the effects of fire, either by means of separation from other spaces in the same building or by virtue of location, thereby permitting a delay in egress travel from any level.

Anchor Building [3]

A building housing any occupancies having low or ordinary hazard contents and having direct access to a mall building, but having all required means of egress independent of the mall.

Common Path of Travel [2]

The portion of exit access that must be traversed before two separate and distinct paths of travel to two exits are available.

Concealed Space [1]

Any part of the space within a building that cannot be seen from an occupied space. This term includes any ceiling space, roof space, space under a raised floor (such as computer rooms, floors, or stages), plenums, spaces under a tiered floor, “left-over spaces” created when some structural element or the like has been covered in; small service or duct spaces within the volume of a firecell and the like, but not a protected shaft.

Dead End [2]

That part of an open path where escape is possible in only one direction.

Exit [2]

That portion of a means of egress that is separated from all other spaces of a building or structure by construction or equipment as required to provide a protected way of travel to the exit discharge.

Exit Access [2]

That portion of a means of egress that leads to an exit.

Exit Discharge [2]

That portion of a means of egress between the termination of an exit and a public way.

Escape Height [2]

The height between the floor level in the firecell being considered and the floor level of the required final exit which is the greatest vertical distance above or below that firecell.

Escape Routes [1]

A continuous unobstructed route from any occupied space in a building to a final exit to enable occupants to reach a safe place, and shall comprise one or more of the following open paths, protected paths and safe paths.

Exitway [1]

All parts of an escape route protected by fire or smoke separations, or by distance when exposed to open air, and terminating at a final exit.

Final Exit [2]

The point at which an escape route terminates by giving direct access to a safe place.

Firecell [2]

Any space including a group of contiguous spaces on the same or different levels within a building, which is enclosed by any combination of fire separations, external walls, roofs, and floors.

Fire Barrier [2]

A continuous membrane or a membrane with discontinuities created by protected openings with a specified fire protection rating, where such membrane is designed and constructed with a specified fire resistance rating to limit the spread of fire, that also restricts the movement of smoke.

Fire Hazard Category [1]

The number (graded 1 to 4 in order of increasing severity), used to classify purpose groups or activities having a similar fire hazard, and where fully developed fires are likely to have similar impact on the structural stability of the building.

Fire Load Energy Density [2]

The total fire load divided by the firecell floor area. In this calculation the floor area shall include circulation and service spaces, but exclude exitways and protected shafts.

Fire Resistance Rating [2]

The term used to describe the minimum fire resistance required of primary and secondary elements as determined in the standard test for fire resistance, or in accordance with a specific calculation method verified by experimental data from standard fire resistance tests. It comprises three numbers giving the time in minutes for which each of the criteria stability, integrity and insulation are satisfied, and is presented always in that order.

Horizontal Exit [3]

A way of passage from one building to an area of refuge in another building on approximately the same level, or a way of passage through or around a fire barrier to an area of refuge on approximately the same level in the same building that affords safety from fire and smoke originating from the area of incidence and areas communicating therewith.

Level of Exit Discharge [3]

(1) The lowest story from which not less than 50 percent of the required number of exits and not less than 50 percent of the required egress capacity from such a story discharge directly outside at grade; (2) the story with the smallest elevation change needed to reach grade where no story

has 50 percent or more of the required number of exits and 50 percent or more of the required egress capacity from such a story discharge directly outside at grade.

Mall Building [3]

A single building enclosing a number of tenants and occupancies wherein two or more

tenants have a main entrance into one or more malls. For the purpose of this *Code*, anchor buildings shall not be considered as a part of the mall building.

Means of Egress [3]

A continuous and unobstructed way of travel from any point in a building or structure to a public way consisting of three separate and distinct parts: (1) the exit access, (2) the exit, and (3) the exit discharge.

Means of Escape from Fire [2]

It is in relation to a building that has a floor area, a) means continuous unobstructed routes of travel from any part of the floor area of that building to a place of safety; and b) includes all active and passive protection features required to warn people of fire and to assist in protecting people from the effects of fire in the course of their escape from the fire.

Means of Escape [3]

Away out of a building or structure that does not conform to the strict definition of means of egress but does provide an alternate way out.

Non-Sleeping Suite [3]

A suite without patient beds intended for overnight sleeping.

Open Paths [1]

That part of an escape route (including dead ends) within a firecell where occupants may be exposed to fire or smoke while making their escape.

Other Property [1]

It means any land or buildings or part of any land or buildings that are: a) not held under the same allotment; or b) not held under the same ownership; and includes a road.

Safe Path [1]

That part of an exitway which is protected from the effects of fire by fire separations, external walls, or by distance when exposed to open air.

Safe Place [1]

A place of safety in the vicinity of a building, from which people may safely disperse after escaping the effects of a fire. It may be a place such as a street, open space, public space or an adjacent building.

Sleeping Suite [3]

A suite containing one or more patient beds intended for overnight sleeping.

Smoke Barrier [2]

A continuous membrane, or a membrane with discontinuities created by protected openings, where such membrane is designed and constructed to restrict the movement of smoke.

Stories in Height [3]

The story count starting with the level of exit discharge and ending with the highest occupiable level containing the occupancy considered.

Suite [3]

A series of rooms or spaces or a subdivided room separated from the remainder of the building by walls and doors.

1 Introduction

1.1 General

The Department of Building and Housing (DBH) in New Zealand is currently undertaking a detailed review of the New Zealand Building Code (NZBC) [4] to match the requirements of the Building Act 2004 (the Act 2004) [5]. The New Zealand Performance Based Design Fire Framework (the framework) [1] has been developed by the DBH and it may become a compulsory methodology for performance-based fire design in the future.

The current NZBC for performance-based fire design has largely qualitative criteria. Proposed buildings meeting the qualitative criteria are based on subjective judgments and uncertainties inherent within the criteria may not be addressed adequately. It means that buildings designed by different fire engineers or accepted by different persons within the Building Consent Authority could contain inconsistent levels of safety. Hence, any construction requiring a building consent could become a complex process and may be delayed due to different interpretations by fire engineers and the Building Consent Authority.

The framework introduces quantitative acceptant criteria, design fire scenarios, and design fires for performance-based fire designs. The methodology and threshold values described in the framework will ensure a more consent outcomes and help smooth the building consent application process [6]. The framework is primarily intended to ensure buildings are designed to a similar level of safety as provided by the existing New Zealand Compliance Document C/AS1 [2]. However, it has not been investigated against international building code – NFPA5000 Building Construction and Safety Code (NFPA5000) [3]. The NFPA5000 specifies prescriptive requirements for a building to ensure an acceptable level of fire safety can be achieved. This research will provide a further comparison of the framework against NFPA5000.

1.2 Research Objective

The objective of this research is to provide a comparative investigation between NFPA5000 [3] and the framework revised on September 2009 [1]. Three complex case study buildings, designed in accordance with NFPA5000, will be analysed using the values and methodology described in the framework. The case study buildings are (1) Single storey retail warehouse, (2) Four storeys hospital and (3) Four storeys shopping mall. The selection of the buildings is based on one or more of the following factor(s): reasonable common use, importance to society and complexity of building layout.

This research will provide feedback to the Department of Building and Housing (DBH) on usability of the framework for performance based fire design as well as provide recommendations for potential changes to the framework. The results will determine if any case study building designed in accordance with NFPA5000 has met the performance measures of the framework. If the case study building fails to pass any of the fire scenarios, the building fails to meet the performance measures of the framework, this could indicate that the framework is more restrictive than the NFPA5000 and potential changes to the framework may be recommended. If the case study building passes all the fire scenarios, the building meets the performance measures of the framework, significant changes will be made to the building to test whether it remains compliant within the framework and feedback will be provided to the DBH.

1.3 Background

1.3.1 The Building Act

Performance-based design has been practiced in New Zealand for some 18 years since establishment of the Building Act in 1991 (the Act 1991) [7] and the New Zealand Building Code (NZBC) in 1992. Before the establishment of the Act 1991, fire safety designs were based on the prescriptive fire safety code [8]. The Act 1991 required all new building to be designed in accordance with the NZBC and the Building Industry Authority (BIA) was thereby established. The performance based building code was administered by the local territorial authorities under regulations developed by BIA. Due to domestic property weathertightness concerns, the Act 1991 was subsequently replaced by the Building Act 2004 (the Act 2004). After the Act 2004 was set up, the Department of Building and Housing (DBH) was established to replace the BIA and improve the building and housing services provided to the public.

The major concern of the Act 2004 is health and safety of building occupants, structural stability, facilitating rescues and the fire fighting operations of the New Zealand Fire Service. Other concerns include energy efficiency and prevention of fire spread to neighbouring buildings. The Building Act is not concerned about fire spread or fire damage within the fire building.

1.3.2 The New Zealand Building Code

The Building Regulations 1992 [9] come under the Act 2004 and the NZBC is the First Schedule to the Building Regulations 1992. Under regulations developed by the DBH, the Building Consent Authority (BCA) administers the performance-based building code. The NZBC is currently undergoing review to incorporate changes in the Act 2004, with the latest review made in 2007 [4].

There are four categories in fire safety requirements, as follows:

C1: Outbreak of fire
C2: Means of escape
C3: Spread of fire
C4: Structural stability during fire

Objective, functional requirement and required performance for each category are the mandatory requirements to meet the NZBC. The designer must achieve the mandatory requirements for each category using acceptable solution or alternative solution given that the mandatory requirements can be demonstrated.

The main performance requirements summarised by Buchanan [10] are listed below:

- Provision of safe egress for occupants
- Provision for safety of fire-fighters
- Prevention of fire spread to neighbouring properties
- Safeguarding the environment from the adverse effects of fire

The NZBC does not specify how designs should be undertaken prescriptively and does not address fire damage caused to the contents of buildings or building structures.

1.3.3 Compliance Documents

Compliance documents (previously known as Approved Documents) are published by the Department of Building and Housing (formerly the Building Industry Authority) to assist designers in complying with the NZBC. Many compliance documents often refer to New Zealand standards. Buildings designed in accordance with compliance documents should be accepted by the Building Consent Authority (formerly Territorial Authority); subsequently, they will automatically be deemed to comply with the NZBC. The compliance document for fire safety is C/AS1 and it is not mandatory for fire safety design.

1.3.4 Current Performance-based Fire Design Approach

Building consent is a formal approval for a building to be built. There are two methods for obtaining a building consent for fire engineering designs: Acceptable Solution using the compliance document C/AS1 published by the DBH or Alternative Solution based on specific fire engineering design. The Acceptable Solution is a prescriptive method and a traditional way for fire safety design. Buildings designed in accordance with the compliance document should be accepted by the BCA, resulting in automatically being deemed to comply with the NZBC. However, due to lack of flexibility with innovative design, it is very difficult to apply in unusual situations and leaves no place for alternative strategies. The Alternative Solution is a performance based method which allows designers to use any fire safety strategy for fire safety design, provided that the NZBC performance requirements are met.

Under the existing system for performance based fire design, the NZBC set out performance requirements for fire safety design. In addition, a fire engineer, in assessing the proposed fire design, recommends the likely design fire, the performance criteria, the worst likely fire location based on their knowledge of the fuel loads, and the location and number of occupants. The current design procedure is basically a trial and error process. The fire engineer should demonstrate that his design meets the NZBC performance requirements by either changing the building geometry or modifying the fire protection features. However, most of any design is founded on an assessed opinion system because performance requirements of the NZBC are qualitative and design is based on subjective engineering judgments. These factors can lead to inconsistent interpretation between fire engineers and the Building Consent Authority and disputes could arise about the safety of fire design for proposed buildings. Performance based fire design, of a quantifiable nature, is becoming recognized around the world but there have been no quantifiable performance or safety statements developed [10]. Once a fire safety design is completed, the design is either checked by the BCA or peer reviewed by an independent consultant before a building consent is issued.

In the past, the documentation and review process for fire engineered alternative solutions were inconsistent because there was no guideline for ensuring that intended design was fully implemented in the final construction stage and the design could therefore be achieved by a number of different strategies and solutions [11, 12]. Currently, the International Fire Engineering Guidelines [13], Fire Engineering Design Guide [14] and Hot Topics [15] provide guidance and recommendations for the designer to carry out fire safety designs that meet the performance requirements of the NZBC. However, most of the guidance has provided a more qualitative direction rather than quantifiable method for performance based fire design.

1.3.5 NFPA5000 Building Construction and Safety Code

The National Fire Protection Association's (NFPA) safety codes and standards have taken part in protecting people and buildings around the world for more than 100 years. The inaugural edition of NFPA5000 was issued in the United States in 2002 for the building industry using the full open consensus process accredited by the American National Standards Institute (ANSI), the administrator and coordinator of the United States private sector voluntary standardisation system [3]. NFPA5000 addresses almost every aspect of design and construction of new and existing buildings including occupant safety from danger caused by fire, smoke and toxic fumes.

There are two paths to follow in order to meet the intentions of NFPA5000 – an approach based on performance-based design or one based on prescriptive-based design. If the designer chooses to follow the performance-based design approach, the building will be tested against the design scenarios specified in the NFPA5000. If the designer chooses to follow the prescriptive-based design approach, the building will be designed in accordance with the occupancy and uses defined in the NFPA5000.

1.3.6 Performance-based Design Fire Framework

A comprehensive review of the NZBC [4] has been undertaken by the DBH to ensure that the current NZBC provides clear and consistent requirements and meet the purpose and principles set out in the Act 2004. It covered requirements for safety, wellbeing, health and sustainable development. The review for performance-based fire design found that:

- the fire safety performance requirements in the NZBC are not clearly stated and qualitative. This means that different people can cause possible delay to the Building Consent Application process by interpreting the requirements in various ways.
- the performance clauses in the NZBC do not provide clear guidance for design fire scenarios, specific values for design parameters, acceptance criteria and characteristics of design fires that must be taken into account when assessing fire engineering design. This has led to inconsistent approach with fire engineering analysis.

After the review, the DBH recommended that the specifications of fire design scenarios, quantitative performance requirements and acceptance criteria should be investigated. As a result, the framework has been developing to improve the above matters.

In the beginning, the framework development was undertaken in collaboration with fire engineering experts. The framework was tested against a series of case study buildings [16] designed in accordance with the compliant document C/AS1. As a result of the analyses, the framework was re-developed and revised. More recently, the viability and usability of the framework for performance-based fire design has been tested by a number of practicing engineers. In additional to this research, the re-developed and revised framework is currently investigated against a series of case study buildings designed in accordance with the compliant document C/AS1.

2 The Performance-based Design Fire Framework

2.1 Introduction

DBH has been developing the framework to provide precise and understandable guidance to meet NZBC specifications. The primary focus of the framework is to provide a clearly defined structure demonstrating compliance with the current performance requirements as specified in the compliant document C/AS1 for performance-based fire design. The framework is expected to be used as a design solution by practicing engineers. Engineers would acquire performance-based fire engineering design to assess against a set of design fire scenarios specified within a robust predetermined framework. The framework would then provide a firmly established method for performance based fire safety design [1].

All performance based design buildings are required to be assessed against ten fire scenarios and acceptance criteria to ensure the NZBC performance requirements have been taken into account when designing for fire safety. To confirm that the proposed fire design is compliant with the NZBC, designers are required to follow the modelling rules, methodologies and applications that are specified in the framework. If any scenario requires an analysis to be made, the result must be compared with the specified acceptance criteria. If the acceptance criteria are met, the design will comply. If the acceptance criteria are not met, a redesign of the building will be necessary. The input values and acceptance criteria analysis for Available Safe Egress Time (ASET) versus Required Safe Egress Time (RSET), prescribed in the framework, provides for a more consistent level of safety in all performance-based fire design [17]. Although some threshold values are enforceable if applied to performance-based fire design for similar usage, flexibility and innovative design are still allowed [1]. Consequently, the framework ensures more consistent outcome, and helps smooth the way for having a building designed and consent obtained [6]. At the same time, it allows for efficient, cost-effective and innovative performance based fire design [6]. The contents of the framework are summarized in Figure 2-1 and the procedures to be taken, using the methodology in the framework, are shown in Figure 2-2.

The following sections of this chapter provide an interpretation based on the actual wording of the framework.

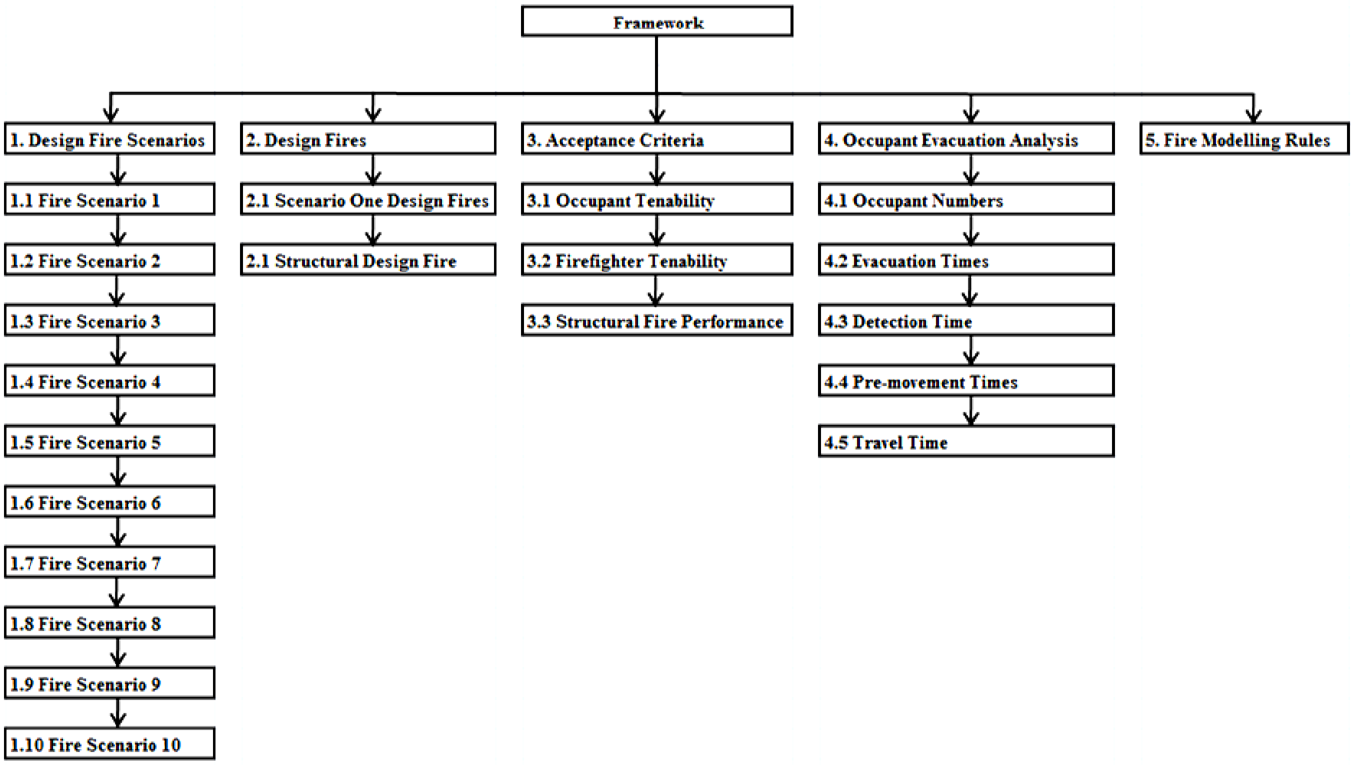

Figure 2-1: Summary of contents in the framework

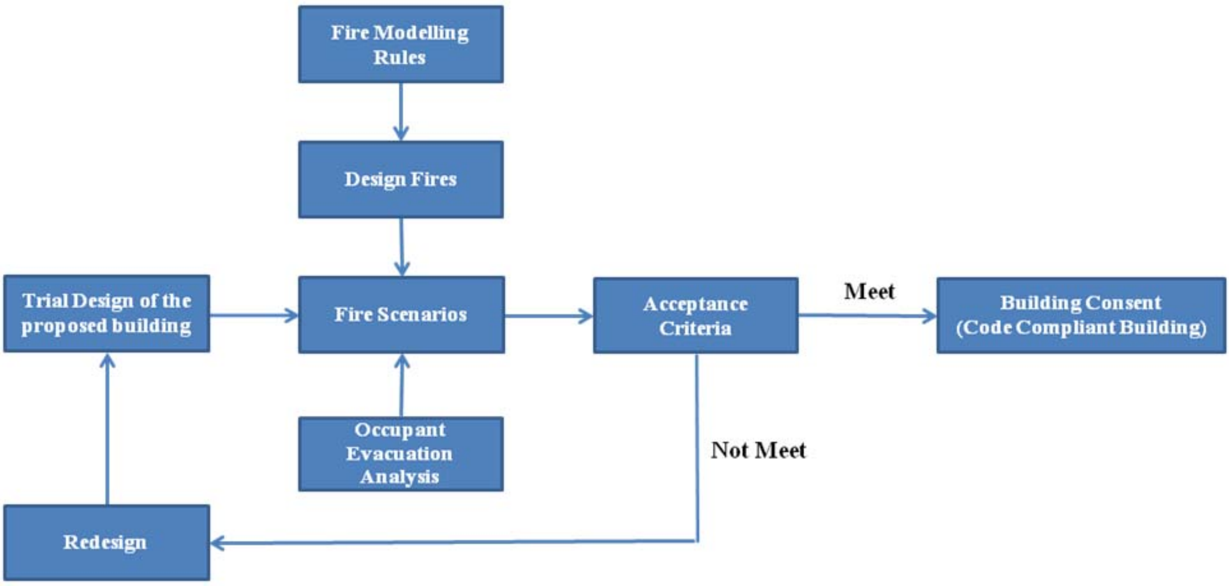

Figure 2-2: Methodology process in the framework

2.2 Design Fire Scenarios

The framework has included ten fire scenarios (Table 2-1). In order to calculate the ASET for similar types of building, the framework has specified the same growth rate and size of fire as well as establishing production rates for smoke and species. When calculating the RSET, occupants with similar response and characteristics have been chosen as the most appropriate in accordance with building type and usage. Each scenario has its own performance objectives, acceptance criteria, methodologies and applications for proposed fire design. Designers are not required to do independent research to calculate the ASET and RSET because the threshold values have been specified within the framework. Some scenarios may not require any calculation or modelling at all, to meet their performance objectives or acceptance criteria.

The design fire scenarios are partly developed from the NFPA5000 [3]. They have been expanded to cover fire spread to neighbouring property and modified to meet NZBC concerns over external vertical fire spread, interior surface finishes and fire fighting facilities. The Design Fire Scenarios are summarised in Table 2-1.

Table 2-1: Summary of Design Fire Scenarios

Design Fire Scenario	Brief Description
Design Fire Scenario One (Challenging Fire)	Occupancy-specific design fire located in several places within a building with all fire safety systems working as intended
Design Fire Scenario Two (Blocked Exit)	A fire blocked an exit may prevent occupants evacuating the building by that route
Design Fire Scenario Three (Fire in Unoccupied Room)	A fire started in an unoccupied room may threaten the occupants in adjacent rooms
Design Fire Scenario Four (Concealed Space)	A fire started in concealed space may threaten the occupants in adjacent rooms
Design Fire Scenario Five (Smouldering Fire)	Smouldering fire may endanger sleeping occupants
Design Fire Scenario Six (Spread to Other Property)	A fire started within a building may spread to neighbouring buildings
Design Fire Scenario Seven (Vertical External Fire Spread)	A fire may expose to an external wall and spread vertically to higher levels of the building
Design Fire Scenario Eight (Interior Surface Finishes)	A fire may ignite interior surface finishes and spread to an escape route

Design Fire Scenario	Brief Description
Design Fire Scenario Nine (Fire Service Operations)	Facilitating fire service operation
Design Fire Scenario Ten (Robustness Check)	Building is evaluated by considering consequences of the failure of key fire safety systems

2.2.1 Design Fire Scenario One (Challenging Fire)

Design Fire Scenario One (DFS1) is intended to represent a challenging fire that will possibly be located in several sections of a building, under a range of acceptance criteria possessing pre-flashover and post-flashover conditions. It will provide a credible, worst-case, scenario to challenge the fire protection features of the building. The design fire characteristics will depend on the use and occupancy of the building. This scenario is summarised in Table 2-2.

Table 2-2: Summary of Design Fire Scenario One (Challenging Fire)

Performance Objective	• Provide a tenable environment for occupants in the event of a fire while they escape to a safe place.
Design Event	• The design fire is characterised with t-squared heat release rate, peak heat release rate, and fire load energy density (FLED). Design values for yields for carbon monoxide (CO), carbon dioxide (CO_2) and soot/smoke are specified. • The details of design fires can refer to section 2.3 and they may be modified during an analysis to account for ventilation effect in building and fire suppression effects in the event of fire.
Performance Criteria	• Occupant Tenability and Structural Fire Performance. • Criteria are detailed in sections 2.4.1 and 0 respectively.
Expected Methodologies	• Provide calculations of the fire environment in the escape routes that will be evacuated using the performance criteria discussed in Section 2.4.
Applications	• Any room/space > 200 m^2; or • Any room/space with occupant load > 150 people; or • Any room > 2 m^2 other than toilet facilities not fire separated from an exitway.

2.2.2 Design Fire Scenario Two (Blocked Exit)

Design Fire Scenario Two (DFS2) describes a situation where an escape route or exit may be blocked due to an accidental or even a deliberately lit fire. A fire is assumed to be located within an exit way or escape route, as described in Design Fire Scenario Two. This scenario tests fire blocking an exit to open or safe passage and ensures an alternative escape route is available for occupants to be evacuated safely. This scenario is summarised in Table 2-3.

Table 2-3: Summary of Design Fire Scenario Two (Blocked Exit)

Performance Objective	• Provide a viable escape route from the building for occupants in the event of fire.
Design Event	• Fire blocking exit in open or safe path. • Fire characteristics don't matter since fire is assumed to physically block the exit.
Performance Criteria	• By inspection (occupant tenability criteria cannot be met where fire plumes and flame block an exit).
Expected Methodologies	• Provide alternative escape routes that are tenable or design single escape routes so that no more than 50 people are served (for open paths) or 150 people (vertical safe paths). Analysis not required. • This scenario applies to individual rooms in the Open path, and to corridors and stairs that are part of an exitway. Single escape routes are permitted to serve up to 50 people.
Applications	• This fire scenario applies to escape route in an open path or horizontal safe path serving more than 50 people; and a vertical safe path serving more than 150 people, or if the building is sprinkler protected, 250 people.

2.2.3 Design Fire Scenario Three (Fire in Unoccupied Room)

Design Fire Scenario Three (DFS3) describes a fire starting in a normally unoccupied room, which may spread to adjacent areas and threaten a large number of occupants. Because the room is unoccupied, the fire may remain undetected and grow to a significant size. This scenario addresses the concern that either fire or smoke may spread to other areas and potentially endanger the maximum number of occupants. The scenario intention is to ensure occupants are evacuated safely and fire fighters are protected during rescue and fire fighting operations. This scenario is summarised in Table 2-4.

Table 2-4: Summary of Design Fire Scenario Three (Fire in Unoccupied Room)

Performance Objective	• Maintain tenable conditions on escape routes until the occupants have evacuated. • Protect against fire spread that could compromise the retreat of fire-fighters.
Design Event	• Use fire characteristics from Design Fire Scenario 1 for the applicable occupancy.
Performance Criteria	• Occupant Tenability and refer to Design Fire Scenario Nine – Fire Service Operations. • They are detailed in section 2.4.1 and 0.
Expected Methodologies	• Include fire separations or fire suppression to confine the fire to room of origin; or • Include automatic detection to provide early warning of the fire in the unoccupied space and inform firefighters about the location of the fire.
Applications	• This fire scenario applies to buildings with rooms/spaces holding more than 50 occupants.

2.2.4 Design Fire Scenario Four (Concealed Space)

Design Fire Scenario Four (DFS4) describes a fire starting in a concealed space, including floor plenums for IT cables, ceiling plenums, service shafts and curtain wall cavities, which may spread to adjacent areas and threaten a high number of occupants. The fire in a non-separated concealed space may go undetected and increase to significant size because neither a detection system nor suppression system is installed. This scenario addresses the concern of fire or smoke spreading to other areas and potentially endangering the maximum number of occupants. This scenario is intended to ensure occupants are evacuated safely and fire fighters are protected during rescue and fire fighting operations. This scenario is summarised in Table 2-5.

Table 2-5: Summary of Design Fire Scenario Four (Concealed Space)

Performance Objective	• Maintain tenable conditions on escape routes until the occupants have evacuated. • Protect against fire spread that could compromise the retreat of fire-fighters.
Design Event	• None.
Performance Criteria	• Occupant Tenability and Firefighter Tenability. • They are detailed in section 2.4.1and 0.
Expected Methodologies	• Fire separations or suppression to confine fire to concealed space. • Automatic detection to provide early warning. • Tenability analysis with fire spreading into the occupied space. • Firefighter tenability on access routes.
Applications	• This fire scenario applies to buildings with rooms/spaces holding more than 50 occupants and concealed spaces. • This scenario does not apply if the concealed space has no combustibles and is less than 0.8 m deep.

2.2.5 Design Fire Scenario Five (Smouldering Fire)

Design Fire Scenario Five (DFS5) describes a slow, smouldering, fire commencing in accommodation quarters and possibly endangering sleeping occupants. Fire in any sleeping area may go unnoticed because a detection system is not installed. This scenario addresses concern over fire or smoke spreading to other areas and potentially endangering sleeping occupants. This scenario is designed to ensure sleeping occupants are alerted to a fire. This scenario is summarised in Table 2-6.

Table 2-6: Summary of Design Fire Scenario Five (Smouldering Fire)

Performance Objective	• Alert sleeping occupants of a fire.
Design Event	• None.
Performance Criteria	• None.
Expected Methodologies	• Provide an automatic smoke detection and alarm system to a recognised standard and no further analysis is required.
Applications	• This fire scenario applies to firecells with a sleeping use.

2.2.6 Design Fire Scenario Six (Spread to Other Property)

Design Fire Scenario Six (DFS6) ensures a large fire is contained within the original building and fire exposure to neighbouring buildings is limited. This scenario indicates that a large fire, contained within a building, has the potential to spread to neighbouring buildings due to heat transfer. Limiting heat transfer to neighbouring buildings can reduce the probability of horizontal fire spread to other buildings by thermal radiation through openings in external walls. This means it is necessary to measure thermal radiation received by neighbouring buildings and test the ignition resistance of building facades and cladding materials. There are two parts of this scenario. The first part addresses the concern that unprotected external walls of a fire building may emit thermal radiation to neighbouring buildings therefore radiation received by the neighbouring property should be limited and reduced to a safe level. The second part specifies that external walls of the building have an acceptable ignition resistance level, in conformity with neighbouring building radiation testing, to further reduce the probability of fire spread to other buildings. This scenario is summarised in Table 2-7.

Table 2-7: Summary of Design Fire Scenario Six (Spread to Other Property)

Performance Objective	• Prevent fire spread to other property and adjacent building/spaces where people sleep.
Design Event	Emitted radiation flux from unprotected areas in external walls (assuming no intervention) shall be taken as: • 88 kW/m^2 for FHC = 1 • 108 kW/m^2 for FHC = 2 • 152 kW/m^2 for FHC = 3 or 4 In the case of a sprinkler protected building the unprotected area is considered to be 6 m^2.
Performance Criteria	1. external walls shall be designed to limit the radiation received on the neighbouring property to: a. no more than 30 kW/m^2 on the relevant boundary; and b. no more than 16 kW/m^2 at 1 m beyond the relevant boundary 2. external walls of building, if located 1 m or closer to a relevant boundary, shall either be of non-combustible construction; or when subjected to a radiant flux of 30 kW/m^2 shall: a. not ignite within 30 minutes (Performance Group III, IV) b. not ignite within 15 minutes (Performance Group I, II)

Expected Methodologies	• C/AS1 tabulated data for boundary distances are acceptable – the theoretical basis for the tabulated data in C/AS1 is given in the following paper: Barnett, C.R. and Wade, C. A. 2002. A Regulatory Approach to Determining Fire Separation between Buildings based on the Limiting Distance Method. Paper presented at the 4th International Conference on Performance Based Codes and Fire Safety Design Methods. Melbourne, Australia. March 2002 • Unprotected areas can be calculated using the given emitted and received radiation levels, boundaries distances and configuration factors • Fire tests of external cladding systems using the cone calorimeter apparatus (ISO 5660) or similar are needed to demonstrate that performance measure 2 above is met unless the cladding is known to be non-combustible (according to AS 1530.1 or similar)
Applications	• All building except those with an Automatic Sprinkler System with a Class A water supply (as defined in NZS 4541)

2.2.7 Design Fire Scenario Seven (Vertical External Fire Spread)

Design Fire Scenario Seven (DFS7) ensures a building has a certain level of resistance to prevent fire spread vertically up to higher floors. This scenario described a fire may spread vertically up the outer face of the external wall of a building via external cladding and cause significant façade damage. A fire in close contact with the external wall could ignite and spread vertically from lower to higher floors in the building, and a fire plume from the fire could emerge from lower to higher window openings. Limiting the maximum HRR or limiting the extent of the vertical flame spread distance from a cladding materials can reduce the probability of occurrence of accelerating flame spread and therefore the HRR released from a cladding materials are required to be measured. There are two parts to this scenario. The first part of the scenario addresses the concern that combustible façade materials may contribute to vertical fire spread, and therefore the maximum HRR from a cladding material shall be limited. The second part of the scenario addresses the concern that window fire plumes may project to higher openings in the building and that can be prevented by providing aprons, spandrels or sprinklers. This scenario is summarised in Table 2-8.

Table 2-8: Summary of Design Fire Scenario Seven (Vertical External Fire Spread)

Performance Objective	• Prevent fire spread to other property and spaces where people sleep (in the same building) and maintain tenable conditions on escape routes until the occupants have evacuated. • Protect against external vertical fire spread that could compromise the safety of firefighters working in or around the building.
Design Event	• Radiant flux of 50 kW/m^2 impinging on the façade for 15 minutes (for Performance Group II and III). • Radiant flux of 90 kW/m^2 impinging on the façade for 15 minutes (for Performance Group IV). • Window plume projecting from opening in external wall, with characteristics determined from design fire for Design Fire Scenario One – Challenging Fire.
Performance Criteria	• Prevent façade cladding materials from contributing to significant flame spread propagation beyond the area initially exposed. Some damage to the area initially exposed will be expected. This may be achieved by limiting the maximum HRR form a cladding material, when exposed to the design event to no more than 100 kW/m^2 or by limiting the extent of the vertical flame spread distance (on the façade) to no more than 3.5 m above the fire source. This accepts fire spread via the façade materials may occur to the floor immediately above, but not two floors above. • In unsprinklered buildings, prevent fire spread from projecting window plumes to unprotected areas on upper floors where they are within 1.5 m vertically of a window plume fire source.

Expected Methodologies	1. Follow exiting C/AS1 and use:
	    a. Large or medium-scale façade type fire tests (e.g. NFPA 285, ISO 13785, VCT)
	    b. Small-scale testing using ISO 5660 or AS/NZS 3837 (cone calorimeter) for homogeneous materials. Limit the maximum HRR from a cladding material to 100 kW/m^2 when exposed to the design event to ensure flame spread over its surface is unlikely.
	2. Use non-combustible materials
	3. Validated flame spread models could be used for some materials
	4. Construction features such as aprons and/or spandrels or sprinkler could be used to meet performance measure 3 above. Window plume characteristics/geometry may be derived from Design Fire Scenario One – Challenging Fire.

Applications	• Buildings where upper floors contain sleeping occupancies or other property. • Buildings of height > 10 m. • This scenario does not apply to Performance Group I buildings.

2.2.8 Design Fire Scenario Eight (Interior Surface Finishes)

Design Fire Scenario Eight (DFS8) ensures a fire source located near a wall would not ignite interior surface linings and finishes for a certain period of time and which may cause occupants unsafe while they evacuate on an escape route. This scenario described room surface lining materials is ignited from a flaming fire source located in a corner of or adjacent to a wall that could lead to untenable conditions on an escape route. This scenario addresses the concern that the interior surface linings and finishes in close contact with a fire could be ignited and contributed to fire growth, and the smoke and toxic gases produce from the surface lining materials could endanger occupants. The time to flashover (combustibility) and the smoke production rate of an interior surface lining material shall be limited in order to reduce the excessive fire products and fire growth. This scenario is summarised in Table 2-9.

Table 2-9: Summary of Design Fire Scenario Eight (Interior Surface Finishes)

Performance Objective	• Tenable conditions on escape routes shall be maintained while occupants evacuate • Protect against rapid fire spread that could compromise the retreat Firefighters
Design Event	• Fire source of output 100kW in contact with a wall-corner element for 10 minutes followed by 300kW for 10 minutes in accordance with ISO 9705
Performance Criteria	Performance criteria for lining materials depend on their location in the building and the occupancy type or building Performance Group. The effect of any fire suppression or smoke management system on the fire development shall be ignored except that the smoke production rate criteria need not apply for sprinkler protected buildings. 1. wall/ceiling materials in exitways; sleeping areas where occupants are detained or under care; and all occupied spaces in Performance Group IV buildings – Time to flashover to be not less than 20 minutes and average smoke production rate over the period 0 – 20 minutes shall be no greater than $5m^2/s$ 2. wall/ceiling materials in assembly/crowd use spaces; sleeping areas where occupants are not familiar with surroundings; and floor surfaces in vertical safe paths – Time to flashover not less than 10 minutes and average smoke production rate over the period 0 – 10 minutes shall be no greater than $5m^2/s$ 3. wall/ceiling materials in all other locations, including within household units and detached dwellings - Time to flashover not less

	than 2 minutes 4. Floor surfaces in horizontal safe paths, assembly/crowd purpose groups and sleeping areas where occupants are detained or under care; and all occupied spaces in Performance Group IV buildings) shall meet floor radiant panel criteria.
Expected Methodologies	• IS0 9705 room corner fire test or ISO 5660 cone calorimeter test results valuated following the procedures described in Wade (2007) • Use non-combustible materials to AS 1530.1 • Use calculations from validated flame spread models (if available for the material and configuration of interest)
Applications	• This fire scenario applies to all buildings, except that the smoke production rate criteria need not apply for sprinkler protected buildings. Criteria need not be applied to small areas of product within a firecell < $5m^2$ or 5% of floor area whichever is greater.

2.2.9 Design Fire Scenario Nine (Fire Service Operations)

Design Fire Scenario Nine (DFS9) ensures firefighters who are authorized by law to enter buildings should not suffer illness and injury during firefighting and rescue operations. Building behaviour is unexpected in a fire environment, and firefighters inside the building may cause illness and injury if they do not have adequate information and facilities to tackle firefighting and rescue operations. The officer who is in charge on the fire ground requires to make the final decision on whether or not firefighters to get into a building. This scenario tests a design have required information for the officer to predict both fire and building behaviour to facilitate the decision making, and provided safe access, adequate facilities and firefighting water for firefighters while undertaking firefighting and rescue operations. Restricting ambient temperature and thermal radiation for a certain period of time would reduce the probability of firefighters working unsafe, and an acceptable level of structural fire resistance in the building where firefighters conducting firefighting and rescue operation is needed to meet. This scenario is summarised in Table 2-10.

Table 2-10: Summary of Design Fire Scenario Nine (Fire Service Operations)

Performance Objective	• Adequate information must be available for firefighters on arrival to enable them to rapidly size-up the situation • Access to all floors of the building must provide firefighter protection • Firefighting water must be available in the vicinity of the fire
Design Event	• The firefighting design fire is 50MW, unless the fire is sprinkler, ventilation or fuel limited at some lower value by the time the fire service arrives.
Performance Criteria	1. Information is available in a conventional manner to facilitate on-site assessment of conditions. 2. Access is available for firefighters to positions from which the fire may be fought and from which safe retreat may be made (refer to criteria for Firefighter Tenability in section 2.4.2). 3. Firefighting water is available in a conventional manner so that it can be used in the vicinity of the fire.
Expected Methodologies	• For performance criteria 1 –features that facilitate rapid size-up of the situation: ➢ Hazardous substance signage ➢ Fire detection system ➢ Panel location and information ➢ Fire service alarm connection ➢ Fire control room ➢ Firefighter control of building fire safety systems ➢ Limitation of fire size by sprinklers or fire cell size • For performance criteria 2 – features that facilitate safe access for rescue and firefighting: ➢ Firefighter access around building ➢ Firefighter control of building fire safety systems ➢ Sprinklers in buildings higher than fire service ladder appliances ➢ No conflict with security systems ➢ Access through tall buildings ➢ Protected from structural collapse ➢ Protected from fire outbreak in the access ➢ Lifts with firefighter controls ➢ Tenable routes through large open spaces (sprinklers and/or effective fire venting) • For performance criteria 3 – features that facilitate adequate firefighting water: ➢ Water is to be available from a pumping appliance parked close to the building such that any point within the building may be reached within 3 hose lengths (75 m);

	➢ An internal hydrant system; ➢ External hydrants plus fire appliance access to building ➢ Internal risers, hydrants and hose reels ➢ Sprinklers
Applications	• Firefighter tenability must be established for large (> 1500m^2) FHC4 buildings, where fire growth rate is very rapid, or for unsprinklered building layouts where the distance from the safe path access to any point on a floor exceeds 75m. • Houses are only required to provide features to facilitate adequate firefighting water.

2.2.10 Design Fire Scenario Ten (Robustness Check)

Design Fire Scenario Ten (DFS10) provides a redundancy and robustness test for fire safety design where one of the key fire safety systems is failed in turn. Key fire systems for this part of scenario include smoke management system, fire sprinklers, automatic fire alarms, and fire and/or smoke doors or similar fire closures. Given that fire sprinklers and automatic fire alarms are installed to a recognised standard, the redundancy and robustness test need not be applied. This scenario describes one of the above key fire systems is failed in turn and an additional fire safety system is required to ensure occupants evacuate to a safe location before an untenable conditions occur. This scenario requires a deterministic ASET and RSET approach for occupants that are more than 150 people in any firecell or more than 6 people in a sleeping occupancy firecell. Tenability criteria need only be based on FED (CO) and FED (thermal), and are referred in section 2.4.1. If a key fire safety system in a design is not presented, this scenario is not required to be performed. This scenario is summarised in Table 2-11.

Table 2-11: Summary of Design Fire Scenario Ten (Robustness Check)

Performance Objective	• Robustness check for ASET calculation from Design Fire Scenario One – Challenging Fire
Design Event	• Each key fire safety system rendered ineffective in turn
Performance Criteria	• Occupant tenability criteria – FED(gases) and FED(thermal) only
Expected Methodologies	• ASET/RSET assessment from DFS1 – Challenging Fire

Applications	• Key fire safety systems include smoke management system, fire and/or smoke doors or similar fire closures; • Where failure to function as designed would expose more than 150 people; or more than 6 people in a sleeping care occupancy firecell to untenable conditions

2.3 Design Fires

The framework requires input of different fire scenarios into proposed fire design. There are two sets of design fires used in the framework: Scenario One Design Fires and Structural Design Fires. These design fires are intended to represent a credible, worst-case, scenario that will challenge the fire protection features of the building. The Scenario One Design Fires are used in some fire scenarios to demonstrate that occupants have sufficient time for escape following a fire in the building. The Structural Design Fire is used to derive the fire resistance of the structure or separating construction. The design fires are detailed in sections 2.3.1 and 0.

2.3.1 Scenario One Design Fires

Design fires are characterised by using parameters. The parameters are fire growth rate, fire load energy density, peak heat release rate, heat of combustion, species production (CO and soot) and heat flux. These are specified for both pre-flashover and post-flashover fires. Depending on use of a building, Scenario One Design Fires can be modelled in accordance with sections 2.3.1.1 and 2.3.1.2.

2.3.1.1 Modelling Pre-flashover Fires

The fire is assumed to grow as a fast t^2 up to flashover (except with the buildings listed in Table 2-12, where H is the storage height in meters and t is time in seconds) and is then either limited by the available ventilation, assuming all windows are broken out or limited to a 20 MW peak heat release rate. If the building is protected by an automatic sprinkler system, the fire is assumed to produce a constant heat release rate, once the sprinklers activate, based on the criteria in section 2.5.2. Pre-flashover species yield for soot (Y_{soot}) is 0.07 kg/kg, pre-flashover species yield for carbon monoxide (Y_{co}) is 0.04 kg/kg and radiative fraction from fire is 0.35. The parameters of the design fires for pre-flashover fires are presented in Table 2-13.

Table 2-12: Exceptions to a fast t^2 fire

Building use	Fire Growth Rate (kW)	Species
Car park	$0.0117t^2$	$Y_{soot} = 0.07$ kg/kg $Y_{co} = 0.04$ kg/kg $\Delta H_c = 20$ MJ/kg
Rack Storage Group 1 (Polystyrene chip in single wall cardboard cartons)	$0.0088t^3H$	$Y_{soot} = 0.07$ kg/kg $Y_{co} = 0.04$ kg/kg $\Delta H_c = 20$ MJ/kg
Rack Storage Group 2 (FMRC Standard Plastic commodity, upholstery cushions)	$0.0025t^3H$	$Y_{soot} = 0.07$ kg/kg $Y_{co} = 0.04$ kg/kg $\Delta H_c = 20$ MJ/kg
Rack Storage Group 3 (FMRC Class II Double triwall cardboard)	$0.00068t^3H$	$Y_{soot} = 0.07$ kg/kg $Y_{co} = 0.04$ kg/kg $\Delta H_c = 20$ MJ/kg

Table 2-13: Pre-flashover Species and Parameters

Species/Parameters	Value
Pre-flashover species yield for soot (Y_{soot})	0.07 kg/kg
Pre-flashover species yield for carbon monoxide (Y_{co})	0.14 kg/kg
Net Heat of Combustion (ΔH_c)	20 MJ/kg
Radiation fraction from fire	0.35
Peak of rate of heat release (free burning)	20 MW

2.3.1.2 Modelling Post-flashover Fires

The time to reach flashover is determined as the time taken to reach 500^{o} C at upper layer, assuming all windows have broken out. The fire is assumed controlled by the ventilation limit or the peak heat release rate, whichever the greatest. For sprinkler-protected buildings, it is assumed the fire has been controlled. Flashover is modelled as linear transition from the growth phase to a fully developed phase during a 15 s period with a heat release rate, under ventilation control, calculated from Equation 1. The fire will continue to develop until the fuel is exhausted, based on the Fire Load Energy Density (FLED) determined from C/AS1 [2]. The parameters of the design fires for post-flashover fires are presented in Table 2-14.

$$\dot{q}_{vl} = 1500 A_o \sqrt{h_o} \qquad \text{Equation 1}$$

where

$\dot{q}_{vl}$ is the ventilation limited heat release rate (kW)

A_o is total area of all openings (m^2)

h_o is average height for all openings (m)

Table 2-14: Post-flashover Species and Parameters

Species/Parameters	Value
Post-flashover species yield for soot (Y_{soot})	0.14 kg/kg
Post-flashover species yield for carbon monoxide (Y_{co})	0.40 kg/kg
Fire load energy density	Can be referenced from the Fire Engineering Design Guide [14]

2.3.2 Structural Design Fires

Design fire characteristics (for Scenario One Design Fires) include parameters for the fire load energy density, fire growth rate and heat of combustion, allowing for a post-flashover structural design fire to be defined. The Structural Design Fire shall be based on complete burnout of the firecell with no intervention.

The engineer could either:

- construct a heat release rate and time structural design fire using these paramenters, taking into account ventilation conditions and using a fire model or energy conservation equations to determine suitable thermal boundary conditions (time/temp/flux) for input to a structural calculation model, or
- use an 'approved' parametric or time-equivalent formula to calculate the thermal boundary conditions (time/temp) for a structural model or the fire resistance rating directly.

The recommended approach to use with this framework is the 'equivalent fire severity' method described in Section 6.4 of the Fire Engineering Design Guide [14]. This allows for the equivalent of a standard fire test exposure time to be estimated, based on compartment properties, fire-load energy density and available ventilation, provided that there has been completed burnout of the fire cell with no intervention.

The effects of sprinkler intervention on a structural design fire can be considered by reducing the design fuel load energy density by 50%. However, most importantly, in the case of primary elements, whose failure could cause disproportionate collapse (e.g. isolated columns in a multi-storeyed building leading to sudden and complete failure), there should be no reduction. In no circumstance should an equivalent structural severity of less than 30 minutes be used.

2.4 Acceptance Criteria

The framework sets out criteria for occupants, firefighters and structural fire performance. The occupant tenability criteria are visibility, FED(thermal) and FED(CO), whilst the firefighter tenability criteria are structural stability, smoke and heat. The criteria for structural fire performance are to prevent fire spread to neighbouring buildings or other property and to facilitate fire fighting and rescue operations. The criteria are presented in sections 2.4.1, 2.4.2 and 0.

2.4.1 Criteria for Occupant Tenability

In an event of a fire, occupants may be exposed to fire and/or smoke. To limit occupants being overcome by the effects of fire, the criteria for occupant tenability are established, as detailed in Table 2-15. These simple criteria must be met; otherwise, the detailed criteria must be used.

Table 2-15: Occupant Tenability

Occupant Tenability Criteria	
Simple Criteria	• Clear layer height about floor not less than 2 m; and • Average upper layer temperature less than 200°C
Detailed Criteria (See Note 1, 2 and 3)	• Visibility not less than 5 m for rooms less than and equal to 100 m^2; • Visibility not less than 10 m for rooms greater than 100 m^2; • Fractional Effective Dose (FED) for carbon monoxide no greater than 0.3; and • Fractional Effective Dose (FED) for thermal effects no greater than 0.3.

Note 1: Visibility, FED (narcotic) and FED (thermal) are measured at a height of 2.0 m above floor level.

Note 2: If an approved automatic sprinkler system is installed, only FED for carbon monoxide applies.

Note 3: The visibility requirement in visibility does not apply within household units.

2.4.2 Criteria for Firefighter Tenability

Fire fighters, conducting search and rescue operations, may have to enter burning buildings. For fire fighters to perform their duties safely, safe access to the fire floor is needed as well as water for fighting the fire. Table 2-16 lists the fire fighter tenability criteria for structural stability, smoke and heat. These criteria permit search and rescue operations, and avoid unexpected or sudden collapse that would endanger fire service personnel, within or near to the building. In addition, fire resistance of the structure or separating construction should be derived from the Structural Design Fire.

Table 2-16: Firefighter Tenability

Firefighter Tenability Criteria – Structural Stability	
In buildings with an escape height > 10 m	• Provide firefighters with safe paths allowing them access to all floors not directly accessible from street level within the building designed to resist burnout; and • Protect firefighters and others at ground level and within the building by designing the load carry structure and floor systems to resist collapse.
In buildings with an escape height < 10 m	• Provide firefighters with safe paths allowing them access to full floors not directly accessible from street level within the building for a period of 60 minutes (from ignition) or to resist burnout whichever is less.
All floors, including intermediate floors	• All floors (including intermediate floors) are required to resist fire from below for a period of at least 30 minutes (from ignition).
Firefighter Tenability Criteria – Smoke and Heat	
Where firefighters have to search large spaces (>1500m^2) with the potential for rapid fire growth, or where the distance from a safe path access to any point on a floor is in excess of 75m	Where firefighters would be expected to operate for a short period of time in high temperatures in combination with direct thermal radiation: • maximum ambient temperature not to exceed 120^{o}C and • maximum radiation not to exceed 3kW/m^2 and • maximum time of 10 minutes

2.4.3 Criteria for Structural Fire Performance

Most building structures are made up of floors, walls and roofs, supported by beams and columns. The failure of a building element occurs if the applied load exceeds the capacity load at any time during exposure to fire. The failure of a building element may result in total collapse of the structure and cause fire spreading to neighboring buildings or adjacent areas in the same building. This occurrence could endanger both fire fighters and occupants alike. Preventing fire spread and facilitating fire fighting and rescue operations are extremely important and the criteria are described in Table 2-17.

Table 2-17: Structural Fire Performance Criteria

Structural Fire Performance Criteria	
Prevent fire spread to neighboring buildings being other property	• This criterion is covered by Design Fire Scenario Six – Spread to Other Property. • The amount of fire resistance required is derived from the Structural Design fire.
Prevent fire spread to other property in the same building or where the importance of the building requires the area of potential fire loss to be limited	• In this case fire spread should be prevented for the full duration/burnout of the fire. • The amount of fire resistance required is derived from the Structural Design fire.
Facilitate fire fighting and rescue operations	• This criterion is covered by Design Fire Scenario Nine – Facilitating fire service operation.

2.5 Occupant Evacuation Analysis

The framework outlines the minimum assessment of occupant evacuation modelling and is not intended to represent a comprehensive evacuation guide analysis. It is expected that designers should be familiar with the occupant evacuation analysis and have a comprehensive understanding of human behaviour. Under occupant evacuation analysis, evacuation time is the time measured from ignition of a fire until occupants can be evacuated to a safe location. The evacuation time (t_{ev}) includes detection time (t_d), pre-movement time (t_p), travelling time (t_t) and queuing time (t_q) and they are expressed in Equation 2.

$$t_{ev} = t_d + t_p + t_t + t_q \qquad \text{Equation 2}$$

2.5.1 Occupant Density

Occupant density is the measurement of people contained along an evacuation route or crowded within a nominated area and is expressed as, users per unit area. As specified in the framework, occupant densities are normally obtained from the existing New Zealand Compliance Document C/AS1 [2]. However, for the purpose of this research, occupant densities have been obtained in accordance with NFPA5000 [3].

2.5.2 Detection Time

Detection time is established from deterministic modelling. This analysis should use an appropriate fire model, incorporating a ceiling jet algorithm that includes an upper layer, or a computational fluid dynamics code that solves the velocity and temperature directly. There are many factors that affect the activation time of detectors, including the installation location, ambient temperature and the fire load. For occupant evacuation analysis, the designer is expected to use the detector values given in Table 2-18, assuming no other, more comprehensive, values are available for the actual detection device specified in the design.

Table 2-18: Recommended values for detector criteria

Residential Sprinklers (3 mm bulb)		**Standard response Sprinklers (5 mm bulb)**	
Response Time Index	36 $m^{1/2}s^{1/2}$	Response Time Index	95 $m^{1/2}s^{1/2}$
Sprinkler C-factor	0.4 $(m/s)^{1/2}$	Sprinkler C-factor	0.4 $(m/s)^{1/2}$
Actuation Temperature	68°C	Actuation Temperature	68°C
Radial distance	2.8 m	Radial distance	2.8 m
Depth below ceiling	0.02 m	Depth below ceiling	0.02 m
Heat detectors		**Smoke detectors**	
Response Time Index	30 $m^{1/2}s^{1/2}$	Optical Density	0.097 (1/m)
Actuation Temperature	57°C	Detector sensitivity	6.6 % per foot
Radial distance	4.2 m	Characteristic length	15 m
Depth below ceiling	0.02 m	Radial distance	7 m
		Depth below ceiling	0.025 m

2.5.3 Pre-movement Times

Pre-movement time is the time assessed from fire detection until when evacuation begins. For occupant evacuation analysis, the designer is expected to use the values shown under Table

2-19 then select pre-movement time, based on building usage and location of the occupants. The values provided in Table 2-19 have been selected from a review of framework literature and comparisons with building examples taken from the existing New Zealand Compliance Document C/AS1 [2].

Table 2-19: Pre-movement times

Description of Building Use	Pre-movement Time (s)
Buildings where the occupants are considered awake, alert and familiar with the building (such as offices, warehouse not open to public)	
Fire cell of origin	30
Remote from the fire cell of origin	60
Buildings where the occupants are considered awake, alert and unfamiliar with the building (such as retail shops, exhibition space and restaurants)	
Fire cell of origin (Standard Alarm Signal)	60
Remote from the fire cell of origin (Standard Alarm Signal)	120
Fire cell of origin (Voice Alarm Signal)	30
Remote from the fire cell of origin (Voice Alarm Signal)	60
Buildings where the occupants are considered sleeping and familiar with the building (such as sleeping residential)	
Fire cell of origin (Standard Alarm Signal)	60
Remote from the fire cell of origin (Standard Alarm Signal)	300
Buildings where the occupants are considered sleeping and unfamiliar with the building (such as sleeping accommodation)	
Fire cell of origin (Standard Alarm Signal)	60
Remote from the fire cell of origin (Standard Alarm Signal)	600
Remote from the fire cell of origin (Voice Alarm Signal)	300
Buildings where the occupants are considered awake and under the care of trained staff (Such as day care, dental office and clinic)	
Fire cell of origin (Independent of Alarm Signal)	60
Remote from the fire cell of origin (Independent of Alarm Signal)	120
Buildings where the occupants are considered to be asleep and under the care of trained staff (Such as hospitals and rest homes)	
Room of origin (Independent of Alarm Signal)	180
Fire cell of origin	300
Remote from the fire cell of origin (Independent of Alarm Signal)	1800
Spaces which have only focused activities (Such as cinemas, theatres and stadiums)	
Room of origin (Independent of Alarm Signal)	0

2.5.4 Travelling Time

Travelling time is the time taken for occupants to travel from an unsafe place to a safe location. For horizontal travel, calculating travel time is based on estimated walking speed. In Equation 3 [18], the relationship between travel speed and occupant density is shown for a population density of between 0.54 and 3.8 persons/m^2. If the population density is less than 0.54 persons/m^2 along the exit route, individuals move independently of others (1.19 m/s). Density is the measurement of people contained within an evacuation route and is expressed, persons per square meter.

$$S = k - akD \qquad \textbf{Equation 3}$$

where

S = travel speed (m/s)
k = 1.4 for horizontal travel, k_2 for vertical travel
a = 0.266
D = occupants density (persons/m^2)

For vertical travel, the maximum speed and the values used for k is a function of the stair riser and tread size as given in Table 2-20.

Table 2-20: Maximum speed and constant for vertical travel

Exit Route Element		k_1	Maximum Speed (m/s)
Riser (m)	Tread (m)		
0.19	0.25	1.00	0.85
0.18	0.28	1.08	0.95
0.17	0.30	1.16	1.00
0.17	0.33	1.23	1.05

As indicated before, travelling time t_t (s) is the time taken for occupants and staff to travel from an unsafe place to a safe location. Travelling distance is the distance measured from the start point to the end point. The start is measured from the remotest point in an unsafe area to the final exit point. Travelling time is related to the travelling distance L (m) and the travelling speed S (m/s), and can be expressed in Equation 4.

$$t_t = \frac{L}{S} \qquad \text{Equation 4}$$

2.5.5 Queuing Time

Queuing time is the time taken for occupants to move through corridors, stairs, doorways or other obstructions. To determine queuing time t_q (s), it is necessary to calculate occupant load N (users), specific flow F_s (users/s/m), actual flow F_a (users/s) and effective width W_e (m). When calculating either specific or actual flow, occupants are assumed to be evenly spread within the area, thus egress time is either governed by queuing time or travel time to the exit, whichever is the greatest [1].

Specific flow is the flow of evacuating people past a defined point in the exit route, per unit of time and per unit of effective width. The maximum specific flow occurs when occupant density is 1.9 persons/m^2 of exit route space. The value of specific flow F_s (users/s/m) can be expressed in terms of any value of occupant density D (users/m^2) and corresponding travel speed S (m/s). They are shown below in Equation 5 to Equation 8 [18]. The maximum specific flow relative to each type of exit route element is listed in Table 2-21.

$$F_s = S \times D \qquad \text{Equation 5}$$

Table 2-21: Maximum specific flow for horizontal and vertical travel

Exit Route Element		Maximum Specific Flow (Person/s/m of effective width)
Corridor, aisle, ramp and doorway		1.3
Riser (m)	**Tread (m)**	
0.19	0.25	0.94
0.18	0.28	1.01
0.17	0.30	1.09
0.17	0.33	1.16

For a stairway, corridor or door width W (m), the effective width W_e (m) is given by [18]:

$$W_e = W - B \qquad \text{Equation 6}$$

where B (m) is the boundary layer width and the thickness of the boundary layer is given in Table 2-22 [18].

Table 2-22: Boundary layer width

Exit Route Element	Boundary Layer (m)
Stairways – wall or side of tread	0.15
Railings, handrails (Note 1)	0.09
Theatre chairs, stadium benches	0
Corridor, ramp walls	0.2
Obstacles	0.1
Wide concourses, passageways	0.46
Door, archways	0.15

Note 1: Where handrails are present, use the value if it results in a lesser effective width

The actual flow of people is when people pass a particular point in an exit route. The actual flow of people F_a (users/s) through the doorway is given by Equation 7 [18]. For doors that are not mechanically held open, a maximum flow rate of 50 users/min/door leaf is suggested [18].

$$F_a = F_s \times W_e \qquad \text{Equation 7}$$

Queuing time t_q (s) to travel through the doorway for occupant load N (users) is given by Equation 8 [18].

$$t_q = \frac{N}{F_a} \qquad \text{Equation 8}$$

2.5.6 Transition

Transitions are any points in the exit system where routes merge or any route dimensions change. For cases involving more than one incoming or one exiting flow stream merging at a transition point, such as that which occurs with stairways merging with individual floor level entry, the equation [18] is expressed as follow:

$$F_{s(out)} = \frac{F_{s(in-1)} W_{e(in-1)} + \ldots + F_{s(in-n)} W_{e(in-n)}}{W_{e(out)}} \qquad \text{Equation 9}$$

where the letter n in the subscripts *(in – n)* and *(out – n)* is a number equal to the total number of routes entering *(in – n)* or leaving *(out – n)* the transition point.

2.6 Fire Modelling Rules

Some of the design fire scenarios in the framework require fire calculation procedures applied to calculate Available Safe Egress Time (ASET) and Required Safe Egress Time (RSET). The framework does not include an approval scheme for fire calculation methods therefore the designer has the freedom to select any appropriate computer fire model or apply hand calculations with the ASET and RSET analysis, as long as fire calculation procedures include accountability of the usage inputs required by the framework and the designer can demonstrate the method meets certain protocols [1]. If computer fire models (e.g. FDS and BRANZFIRE) are chosen, the framework provides fire-modelling rules to determine the ASET and the RSET. The rules for computer fire models are mandatory and require full implementation. The modelling rules are listed below:

- There must be some way to alert the occupants
- Fire/Smoke doors with self closers are assumed closed unless occupants are escaping through them. During egress, doors are assumed to be open for three seconds per occupant or for the duration of queuing whichever is the lesser
- Doors without self-closers are assumed to be open during the analysis
- Egress doors are assumed to be half-width for ventilation flow calculation
- Smoke control doors are assumed to have zero leakage area
- Fire rated construction is considered to have no leakage
- Unrated walls are assumed to have leakage areas that are proportional to the surface area of the walls. Leakage area is equal to the wall area multiplied $0.001m^2/\ m^2$. In zone modelling leakage should be modelled as tell narrow slot from floor to ceiling with the width of the vent determined by the calculated area. In CFD modelling leakage should be modelled either as a vertical slot as in zone modelling or as two vents one at floor and ceiling levels to fit within the computational grid. Fire rated walls are considered to have a leakage area of 0
- Fire rated doors that are not smoke control doors are assumed to have 10 mm gap over the height of the door (nominally a 3mm gap on four sides)
- Windows are assumed to break either at 500^oC or when the fire becomes limited by ventilation and the heat release rate reduces whichever occurs sooner

- The base of the fire is assumed to be located 0.4 m above floor level

3 Methodology

3.1 Introduction

In this chapter, the methods and analyses adapted in this research are presented. It includes a brief description of the case study buildings and fire computer models used to simulate the fire environment within the buildings. This research is completed in three stages:

- Stage One – Case Study Building Design and Audit
- Stage Two – Applying the Framework to the Case Study Buildings
- Stage Three – Result Analysis

3.1.1 Stage One – Case Study Building Design and Audit

Three complex case study buildings (retail warehouse, hospital and shopping mall) are designed in accordance with the minimum prescriptive requirements of NFPA5000. Each building is provided with the minimum fire protection and life safety requirements specified in NFPA5000. The requirements are fire resistance construction, fire detection system, fire suppression system, interior finish, means of egress and firefighting. Once the buildings have been designed, they are audited by a professional engineer to insure compliance.

3.1.2 Stage Two – Applying the Framework to the Case Study Buildings

The framework has specified ten fire scenarios and each scenario has its own acceptance criteria, methodology and application. For those fire scenarios that require ASET and RSET analysis, the design fires are located in several places in the buildings and the case study buildings are analysed against the scenarios for a range of acceptance criteria. The framework sets up modelling rules for fire computer modelling, and specifies the input parameters and acceptance criteria to determine ASET and RSET. The ASET is obtained from Fire Dynamics Simulator (FDS) [19] and BRANZFIRE [20] when one or more acceptance criteria are exceeded while occupants within a building or within its escape route. The RSET is obtained from hand calculations. For other fire scenarios, the case study buildings are assessed against the performance measures specified in the framework.

3.1.3 Stage Three – Results Analysis

The results from stage two are investigated so that the research can provide feedback to the DBH on usability of the framework for performance based fire design and provide recommendations for potential changes to the framework. The results determine the case study building designed in accordance with NFPA5000 has met the performance measures of the framework. If the case study building fails to pass any of the fire scenarios, the building fails to meet the performance measures of the framework, the framework is more restrictive than NFPA5000 and potential changes to the framework may be recommended. If the case study building passes all the fire scenarios, the building meets the performance measures of the framework, significant changes are made to the building to test if it is still complied with the framework and feedback is provided to the DBH.

3.2 Case Study Buildings

Three case study buildings are chosen in this research to represent a range of common use and occupant characteristics of buildings. They do not necessary represent the worst case or the most onerous design in terms of occupant number, building construction, building size or complexity. The case study buildings are a retail warehouse, a hospital and a shopping mall. Table 3-1 outlines the case study buildings investigated in this research.

The first case study building is retail warehouse. It has the potential for rapid fire growth and large number of occupants (>500). The occupants are unfamiliar with the building. The building is reasonably common, posing normal risk to building occupants and normal economic cost to society, and is described in section 4.1.

The second case study building is a hospital. It is essential to post-disaster recovery and must continue to function 24/7. Many of the occupants are asleep and suffering from physical or mental disability and may not be capable of self-preservation. The building is important to society and is described in section 5.1.

The third case study building is a large shopping mall. It is a public place with potential for rapid fire growth, large numbers of occupants (>10000). The occupants are unfamiliar with the building and a wide range of retail tenants with a wide variety of fire development potential. The building is reasonably common, complex and house large numbers of occupants, and is described in section 6.1.

Table 3-1: Case Study Buildings

Case Study Building Number	Case Study Building Name	Occupancy as defined by NFPA5000
1	Retail Warehouse	• Mercantile Class B
2	Hospital	• Health Care • Residential • Business • Assembly • Ambulatory Health Care
3	Shopping Mall	• Mercantile Class A • Assembly • Storage

3.3 ASET and RSET Analysis

The framework sets out performance criteria for occupant tenability to determine the time for conditions to become life threatening. The occupants must be able to clear an area before the life threatening conditions occur in the area. The times in relation to the above matters are Available Safe Egress Time (ASET) and Required Safe Evacuation Time (RSET).

Available Safe Egress Time (ASET) is defined as the time between ignition of a fire and the onset of untenable conditions in a specific part of a building. Fire computer models (such as BRANZFIRE and FDS) can be used to calculate the time when certain performance criteria are exceeded. The performance criteria are visibility, FED(thermal) and FED(CO).

Required Safe Evacuation Time (RSET) is defined as the time required for safe evacuation of occupants to a place of safety prior to the onset of untenable conditions. It is a function of detection time, pre-movement time, travel time and queuing time, where the egress time is either governed by the travel time or the queuing time to the exit, whichever was greater. The framework describes a minimum level of analysis and a number of excellent references on evacuation calculation which includes detection time and pre-movement time, and travel time and queuing time. The detection time is determined from computer fire model with recommended values for detector criteria given from the framework, the occupant's pre-movement times are selected the most appropriate in accordance with the building use specified in the framework, and equations for travel time and queuing time are based on [18, 21-24].

The ASET using performance criteria for occupant tenability is compared with the RSET. ASET must be greater than RSET to demonstrate that the occupants have sufficient time to evacuate the building before being overcome by the effects of fire. For traditional fire engineering practice, ASET should be greater than RSET by a safety margin to account for uncertainty or error. In this research, there is no safety margin allowed in the calculation as the objective of this research is to provide a comparative investigation between NFPA5000 and the framework. For an example in Design Fire Scenario One, a case study building passes the scenario if the ASET is greater than the RSET and a case study building fails the scenario if the ASET is less than the RSET.

3.4 Fire Computer Models

Fire environments within each case study building are simulated using fire computer model with the fire modelling rules outlined in the framework. The fire computer models are BRANZFIRE and FDS. A brief description of each of the models is described in the following two sections.

3.4.1 BRANZFIRE

BRANZFIRE 2009 (Version 2009.24) is used to perform the simulations of the case study buildings. It is a computer-based fire modelling program and a zone model to predict fire growth and fire spread in a space. The zone model divides a case study building into a number of compartments (maximum of 10) with an optional unlimited number of wall vents and ceiling vents connecting each other. Each compartment is divided into two layers (a hot upper layer and a cold lower layer) and is interactive between the two zones by a set of time dependent distribution of smoke and heat from a burning object. The zone model has been developed at BRANZ and is able to calculate the detection time and sprinkler activation time, and output variables such as upper and lower layer temperatures, FED for thermal exposure, FED for carbon monoxide and visibility in a space.

3.4.2 Fire Dynamic Simulation

Fire Dynamic Simulation 5 (FDS5), version 5.4.2, is used to perform the simulations of the case study buildings. It is a computer-based fire modelling program and a three-dimensional Computational Fluid Dynamics (CFD) models to simulate fire behaviour as it develops in a building. The CFD model divides a case study building into many thousands of rectangular meshes and solves dependent variables at each mesh point using the governing equations. The variables include temperature, visibility, FED for carbon monoxide, heat flux and much more. FDS5 has been developed at the National Institute of Standards and Technology (NIST) in cooperation with VTT Building and Transport and the outputs from it can be visualised using an application called SmokeView [25] in an interactive three-dimensional environment.

4 Case Study Building One (Retail Warehouse)

4.1 Building Description

The building is a single storey retail warehouse with a mezzanine floor located at the west side of the warehouse. The ground floor of the warehouse contains retail area, drive thru area, storage room and toilet facilities. The mezzanine is used for offices and staff rooms. The retail area is the main area and is located at the centre of the warehouse. The drive thru area and storage room were on the east and west side of the building respectively. The building is one firecell and contains rack storage to a maximum height of 5.0 m in retail area, storage area and drive thru area.

The building was 40.0 m wide, 60.0 m long and 8.0 m height. The West wall is 0.1 m to the relevant boundary, the North wall is 7.0 m to the relevant boundary, the East wall is 22.0 m to the relevant boundary and the South wall is 30.0 m to the relevant boundary. The ground floor and mezzanine plan are shown in Figure 4-1 and Figure 4-2 respectively.

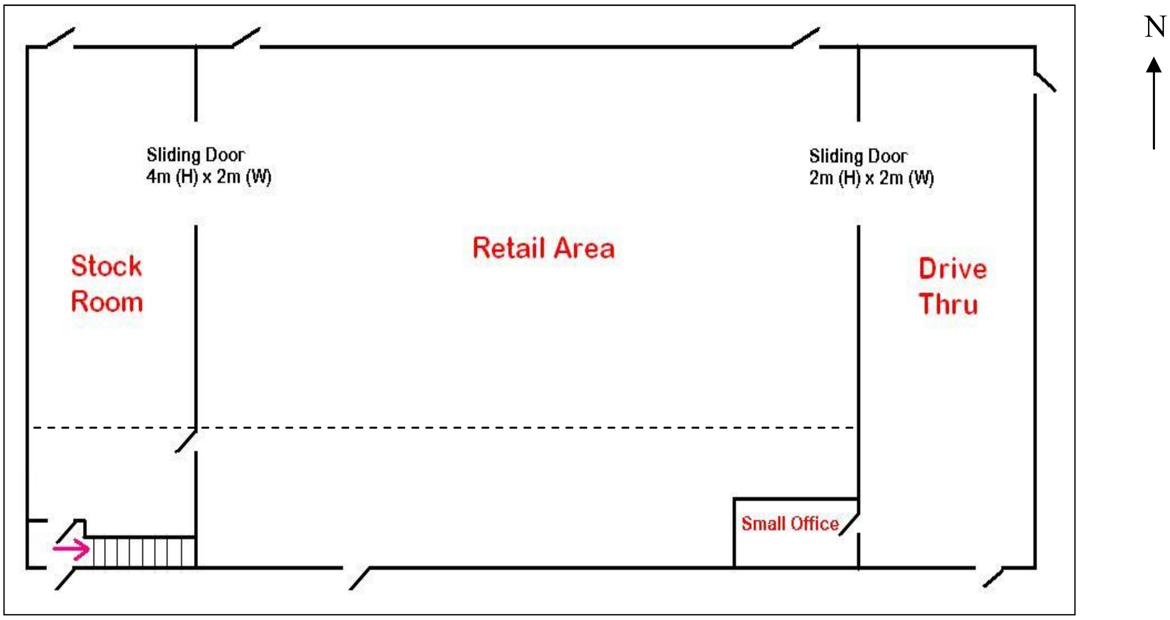

Figure 4-1: Plan view of stock room, retail area, drive thru area and small office in retail warehouse (not to scale)

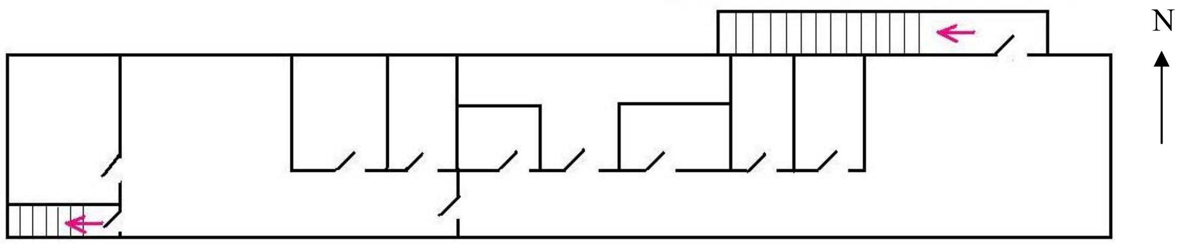

Figure 4-2: Plan view of Mezzanine and Offices in retail warehouse (not to scale)

4.2 NFPA5000 Audit

The retail warehouse will satisfy the prescriptive requirement of the NFPA5000 if the following fire requirements are implemented. A detailed NFPA5000 audit report including building layouts, relevant boundaries, occupancy types, occupant loads, required fire protection systems and exits and egress routes can be found in Appendix A1.

- The building is protected by an approved, supervised automatic sprinkler system in accordance with NFPA13
- The stairway at mezzanine level is not required to provide fire resistance rating or smoke barriers for walls and door assemblies
- The West exterior wall of the warehouse requires a fire resistance rating of 2 hours
- The small office is compliant in that there is only a single means of egress at ground level. Retail area, storage area, drive thru area and mezzanine are provided at least two means of egress and at least two accessible means of egress
- Inside open stairway is permitted to use as a means of egress at the mezzanine level
- The minimum 0.915 m clear stair width for discharge from a stairway has been achieved. The stairway width is 1.2 m and the height between landings is 3.5 m. The tread depth and the riser height of the stairs are 0.33 m and 0.175 m respectively
- The minimum horizontal length of the staircase including landings is 9.0 m

4.3 Design Fire Scenario One (Challenging Fire)

The framework defines a set of design fire scenarios to evaluate the case study building. The first design fire scenario is DFS1 which provides a credible worst case scenario to challenge the fire protection features of the building. In this scenario, occupancy-specific design fires locate in several places within the building with all fire safety systems working as intended.

4.3.1 Description of Fire Modelling in BRANZFIRE

The retail warehouse was modelled into five distinct regions (Figure 4-3) which included storage area, retail area, drive thru area, stairway and mezzanine floor. Retail area, clear room and accessible water closet were modelled as one room by taking into account their combined volume and maintaining the same height and length of retail area. Drive thru area and small office at the ground floor were modelled as one room by maintaining the same height and depth of the drive thru and their volume. Mezzanine floor, stairway and stock room were modelled as its own room. The room dimensions are shown in Table 4-1.

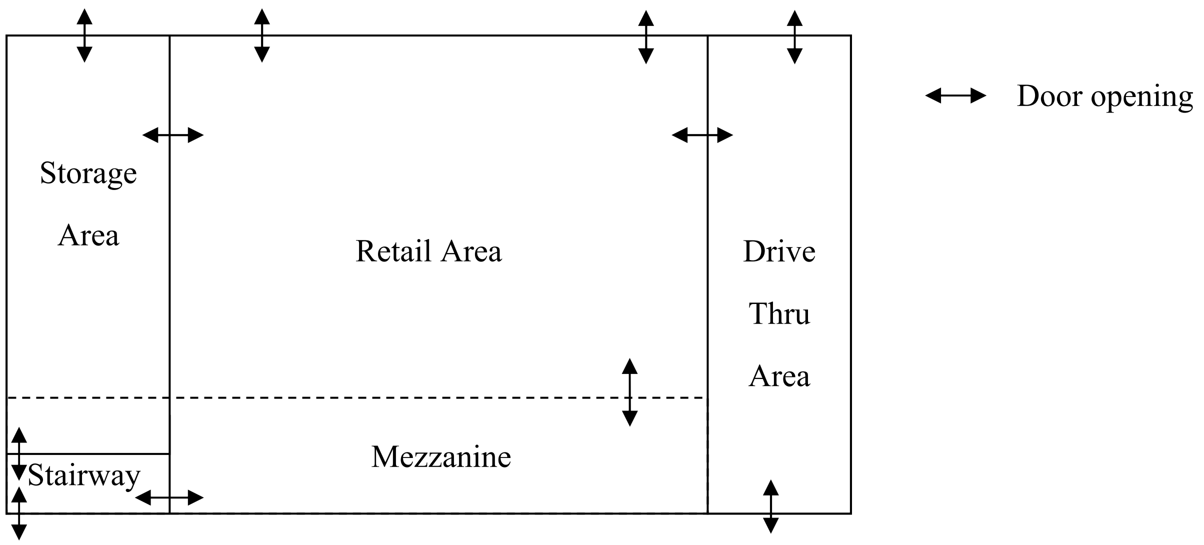

Figure 4-3: Case Study Building One (Retail Warehouse) BRANZFIRE modelling

Table 4-1: Summary of room dimensions included in retail warehouse BRANZFIRE modelling

Room	Width (m)	Depth (m)	Height (m)	Floor Height (m)
(1) Retail area	43.8	37.2	8.0	0.0
(2) Stock room	8.6	35.6	8.0	0.0
(3) Drive thru area	10.9	39.0	8.0	0.0
(4) Stairway	6.3	1.2	5.9	0.0
(5) Mezzanine floor	50.5	5.5	2.4	3.5

Windows and a number of vents connected between rooms or between room and the outside of the building were modelled in accordance with the fire modelling rules described in section 2.6. All doors including exterior doors are open because all doors are without self-closing devices. All interior walls are not fire rated and the leakage area, at the rate of $0.001m^2/m^2$, has been included in the modelling analysis. Doors used for egress are normally open for duration of modelling. Figure 4-3 and Table 4-2 provide the details of the vents used in BRANZFIRE between compartments and to the outside. Construction materials for walls, floors and ceilings in each of the five rooms modelled in BRANZFIRE are shown in Table 4-3. The stairway was modeled as a single zone where a two-zone environment was less likely to occur [26]. All other rooms were modeled as a two-zone environment.

Table 4-2: Summary of vent dimensions connecting rooms included in retail warehouse BRANZFIRE modelling

Room	Vent width (m)	Vent height (m)	Sill Height (m)	Opening Time (s)	Closing Time (s)	Function
Retail Area to Stock Room	2.0	4.0	0	Always	None	Door
Retail Area to Stock Room	0.81	2.03	0	Always	None	Door
Retail Area to Stock Room	0.04	6.5	0	Always	None	Leakage
Retail Area to Drive Thru	2.0	2.03	0	Always	None	Door
Retail Area to Drive Thru	0.04	6.5	0	Always	None	Leakage
Retail Area to Outside	3.1	2.03	0	Always	None	Door
Retail Area to Outside	0.09	6.5	0	Always	None	Leakage
Retail Area to Mezzanine	0.81	2.03	3.5	Always	None	Door
Retail Area to Mezzanine	0.04	3.0	3.5	Always	None	Leakage
Retail Area to Mezzanine	2.0	1.0	4.5	None	None	Windows
Stock Room to Mezzanine	0.01	3.0	3.5	Always	None	Leakage
Stock Room to Stairway	0.81	2.03	0	Always	None	Door
Stock Room to Outside	0.81	2.03	0	Always	None	Door
Stock Room to Outside	0.01	6.5	0	Always	None	Leakage
Stairway to Mezzanine	0.81	2.03	3.5	Always	None	Door
Stairway to Outside	0.81	2.03	0	Always	None	Door
Drive Thru to Outside	1.62	2.03	0	Always	None	Door
Drive Thru to Outside	0.06	6.5	0	Always	None	Leakage
Drive Thru to Mezzanine	0.01	3.0	3.5	Always	None	Leakage
Mezzanine to Outside	8.0	1.0	1.0	None	None	Windows
Mezzanine to Outside	0.05	3.0	0	Always	None	Leakage

Table 4-3: Summary of surface, material and substrate for various rooms in retail warehouse BRANZFIRE modelling

Room	Wall Material	Ceiling Material	Floor Material
	Surface	Surface	Surface
(1) Retail area	Concrete	Mild Steel	Concrete
(2) Stock room	Concrete	Mild Steel	Concrete
(3) Drive thru area	Concrete	Mild Steel	Concrete
(4) Stair	Concrete	Mild Steel	Concrete
(5) Mezzanine floor	Concrete	Mild Steel	Concrete

4.3.2 Design Fire

The area of retail area, storage area, drive thru area and mezzanine were greater than 200 m^2 and were required to be analysed under DFS1. The design fire growth rates in different areas and the peak heat release rate from BRANZFIRE modelling are detailed in Table 4-4. The building stored materials in racks up to 5.0 m high and they were located in the retail area, storage area and drive thru area. The design fire in all areas except the mezzanine was assumed to grow as a rack storage Group 1 t^3 because it gives the most severe fire out of the three rack storage groups. The mezzanine had a fast t^2 fire growth rate.

All windows were not broken as the upper temperature was not reached 500 ^oC, or the heat release rate was not reduced after the fire reaches peak heat release rate. Therefore, it was decided that none of the windows were broken as required by the modelling rules specified in the framework.

Table 4-4: Design fires from BRANZFIRE modelling

Fire Location	Fire Growth Rate (kW)	Time to reach 500°C or when the Heat Release Rate reduces (s)	Peak Heat Release Rate (MW) from BRANZFIRE Modelling
Retail Area	$0.044t^3$	Not Reach	20.0
Storage Area	$0.044t^3$	Not Reach	15.1
Drive thru	$0.044t^3$	Not Reach	16.4
Mezzanine	$0.047t^2$	Not Reach	0.91

Soot and carbon monoxide production rate used in the BRANZFIRE modelling are listed below:

- Pre-flashover species yield for soot (Y_{soot}) is 0.07 kg/kg
- Pre-flashover species yield for carbon monoxide (Y_{co}) is 0.04 kg/kg
- Post-flashover species yield for soot (Y_{soot}) is 0.14 kg/kg
- Post-flashover species yield for carbon monoxide (Y_{soot}) is 0.40 kg/kg

4.3.3 BRANZFIRE Modelling Results to determine ASET

The framework sets out modelling rules to modify the building design and the building was modelled in the BRANZFIRE. The fire modelling rules of the framework required some way to alert the occupants. An automatic sprinkler system was required from NFPA5000 and was installed throughout the building in order to control and suppress the fire as well as to alert the occupants. The BRANZFIRE results summarized in Table 4-5 show the time to reach occupant tenability criteria in Retail Area, Stock Room, Drive Thru, Staircase and Mezzanine for fire located in various areas within the retail warehouse.

To determine the ASET, the building was required to be tested against the simple criteria and detail criteria. Since the upper layer descends to less than 2.5 m measured from the floor level within the simulation time, the detailed tenability criteria was required to be addressed. Sprinkler system was installed throughout the building therefore the criterion for occupant tenability was based on FED for CO gases only.

Table 4-5: BRANZFIRE results for the tenability criteria given in the framework for DFS1 for the retail warehouse fire.

Fire Located in Retail Area (Retail Area Fire)			
Room	**Visibility (10m)**	**FED (Thermal)**	**FED (CO)**
Retail Area	195s	219s	741s
Stock Room	216s	578s	1093s
Drive Thru	172s	1380s	1610s
Staircase	> 1800s	> 1800s	> 1800s
Mezzanine	126s	1690s	> 1800s
Fire Located in Stock Room (Stock Room Fire)			
Room	**Visibility (10m)**	**FED (Thermal)**	**FED (CO)**
Retail Area	244s	644s	1180s
Stock Room	74s	90s	346s
Drive Thru	406s	> 1800s	> 1800s

Staircase	83s	180s	897s
Mezzanine	97s	> 1800s	> 1800s
Fire Located in Drive Thru (Drive Thru Fire)			
Room	**Visibility (10m)**	**FED (Thermal)**	**FED (CO)**
Retail Area	472s	170s	1730s
Stock Room	483s	> 1800s	> 1800s
Drive Thru	83s	99s	290s
Staircase	301s	> 1800s	> 1800s
Mezzanine	128s	> 1800s	> 1800s
Fire Located in Mezzanine (Mezzanine Fire)			
Room	**Visibility (10m)**	**FED (Thermal)**	**FED (CO)**
Retail Area	> 1790s	> 1790s	> 1790s
Stock Room	> 1790s	> 1790s	> 1790s
Drive Thru	> 1790s	> 1790s	> 1790s
Staircase	144s	> 1790s	1210s
Mezzanine	96s	272s	896s

4.3.4 RSET Calculations

All occupants in the building are assumed to be awake as the primary use of the building is not for sleeping purpose. The retail area and the drive thru area are open to public and the occupants are assumed to be unfamiliar with the escape routes. The storage area and the offices on the mezzanine are not for public access and the employees are considered familiar with escape routes. The calculations of RSET were explained in section 2.5. RSET is a sum of detection time, pre-movement time, and travel time or queuing time. A summary of evacuation time for the retail fire, storage fire, drive thru fire and mezzanine fire are provided in Table 4-6 to Table 4-9 and Appendix B.

Table 4-6: Required inputs to determine the evacuation time for retail area fire

FIRE LOCATED IN RETAIL AREA (RETAIL FIRE)			
Component		**Value**	**Remark**
Detection Time (s)	t_d	77	Sprinkler activation time
RETAIL AREA (ROOM OF FIRE ORIGIN)			
Pre-movement Time (s)	t_p	60	The occupants are awake and unfamiliar with the building (Room of fire origin)
Travel Time (s)	t_t	28	Travel to outside
Queuing Time (s)	t_q	246	Clear occupants to outside
RSET (s) – Clear retail area		383	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 77+60+246=383
Storage Area			
Pre-movement Time (s)	t_p	60	The occupants are awake and familiar with the building (remote from the room of fire origin)
Travel Time (s)	t_t	23	Travel to outside
Travel Time (s)	t_t	24	Travel to stairway
Queuing Time (s)	t_q	9	Clear occupants to outside
Queuing Time (s)	t_q	22	Clear occupants to stairway
RSET (s) – Clear storage area to outside		160	Queuing time is not included in the RSET because the travel time is dominant (Occupants are travelling rather than queuing) 77+60+23=160
RSET (s) – Clear storage area to the outside through stairway		161	Queuing time is not included in the RSET because the travel time is dominant (Occupants are travelling rather than queuing) 77+60+24=161
Drive Thru Area			
Pre-movement Time (s)	t_p	120	The occupants are awake and unfamiliar with the building (remote from the room of fire origin)
Travel Time (s)	t_t	20	Travel to outside
Queuing Time (s)	t_q	11	Clear occupants to outside
RSET (s) – The last occupant to clear the building		217	Queuing time is not included in the RSET because the travel time is dominant (Occupants are travelling rather than queuing) 77+120+20=217
Mezzanine			
Pre-movement Time (s)	t_p	60	The occupants are awake and familiar with the building (remote from the room of fire origin)

Travel Time (s)	t_t	20	Travel to open stairway
Travel Time (s)	t_t	29	Travel to outside through enclosed stairway
Travel Time (s)	t_t	64	Travel to outside through retail area
Queuing Time (s)	t_q	22	Queuing at open stairway
Queuing Time (s)	t_q	22	Queuing at enclosed stairway on ground floor
Queuing Time (s)	t_q	246	Queuing at retail area
RSET (s) – Clear mezzanine to open stairway		159	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 77+60+22=159
RSET (s) – Clear mezzanine to the outside through enclosed stairway		166	Queuing time is not included in the RSET because the travel time is dominant (Occupants are travelling rather than queuing) 77+60+29=166
RSET (s) – Clear mezzanine to the outside through retail area		383	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 77+60+246=383

Table 4-7: Required inputs to determine the evacuation time for storage area fire

FIRE LOCATED IN STORAGE AREA (STORARE FIRE)			
Component		**Value**	**Remark**
Detection Time (s)	t_d	70	Sprinkler activation time
Retail Area			
Pre-movement Time (s)	t_p	120	The occupants are awake and unfamiliar with the building (remote from the room of fire origin)
Travel Time (s)	t_t	28	Travel to outside
Queuing Time (s)	t_q	246	Clear occupants to outside
RSET (s) – Clear retail area		436	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 70+120+246=436
STORAGE AREA (ROOM OF FIRE ORIGIN)			
Pre-movement Time (s)	t_p	30	The occupants are awake and familiar with the building (Room of fire origin)
Travel Time (s)	t_t	23	Travel to outside
Travel Time (s)	t_t	24	Travel to stairway
Queuing Time (s)	t_q	9	Clear occupants to outside
Queuing Time (s)	t_q	22	Clear occupants to stairway
RSET (s) – Clear storage area to outside		123	Queuing time is not included in the RSET because the travel time is dominant (Occupants are travelling rather than queuing) 70+30+23=123
RSET (s) – Clear storage area to the outside through stairway		124	Queuing time is not included in the RSET because the travel time is dominant (Occupants are travelling rather than queuing) 70+30+24=124
Drive Thru Area			
Pre-movement Time (s)	t_p	120	The occupants are awake and unfamiliar with the building (remote from the room of fire origin)
Travel Time (s)	t_t	20	Travel to outside
Queuing Time (s)	t_q	11	Clear occupants to outside
RSET (s) – The last occupant to clear the building		210	Queuing time is not included in the RSET because the travel time is dominant (Occupants are travelling rather than queuing) 70+30+20=210

Mezzanine			
Pre-movement Time (s)	t_p	60	The occupants are awake and familiar with the building (remote from the room of fire origin)
Travel Time (s)	t_t	20	Travel to open stairway
Travel Time (s)	t_t	29	Travel to outside through enclosed stairway
Travel Time (s)	t_t	64	Travel to outside through retail area
Queuing Time (s)	t_q	22	Queuing at open stairway
Queuing Time (s)	t_q	22	Queuing at enclosed stairway on ground floor
Queuing Time (s)	t_q	246	Queuing at retail area
RSET (s) – Clear mezzanine to open stairway		152	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 70+60+22=152
RSET (s) – Clear mezzanine to the outside through enclosed stairway		159	Queuing time is not included in the RSET because the travel time is dominant (Occupants are travelling rather than queuing) 70+60+29=159
RSET (s) – Clear mezzanine to the outside through retail area		376	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 70+60+246=376

Table 4-8: Required inputs to determine the evacuation time for drive thru area fire

FIRE LOCATED IN DRIVE THRU (DRIVE THRU FIRE)			
Component		**Value**	**Remark**
Detection Time (s)	t_d	72	Sprinkler activation time
Retail Area			
Pre-movement Time (s)	t_p	120	The occupants are awake and unfamiliar with the building (remote from the room of fire origin)
Travel Time (s)	t_t	28	Travel to outside
Queuing Time (s)	t_q	246	Clear occupants to outside
RSET (s) – Clear retail area		438	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 72+120+246=438
Storage Area			
Pre-movement Time (s)	t_p	60	The occupants are awake and familiar with the building (remote from the room of fire origin)
Travel Time (s)	t_t	23	Travel to outside
Travel Time (s)	t_t	24	Travel to stairway
Queuing Time (s)	t_q	9	Clear occupants to outside
Queuing Time (s)	t_q	22	Clear occupants to stairway
RSET (s) – Clear storage area to outside		155	Queuing time is not included in the RSET because the travel time is dominant (Occupants are travelling rather than queuing) 72+60+23=155
RSET (s) – Clear storage area to the outside through stairway		156	Queuing time is not included in the RSET because the travel time is dominant (Occupants are travelling rather than queuing) 72+60+24=456
DRIVE THRU AREA (ROOM OF FIRE ORIGIN)			
Pre-movement Time (s)	t_p	60	The occupants are awake and unfamiliar with the building (Room of fire origin)
Travel Time (s)	t_t	20	Travel to outside
Queuing Time (s)	t_q	11	Clear occupants to outside
RSET (s) – The last occupant to clear the building		152	Queuing time is not included in the RSET because the travel time is dominant (Occupants are travelling rather than queuing) 72+60+20=152

Mezzanine			
Pre-movement Time (s)	t_p	60	The occupants are awake and familiar with the building (remote from the room of fire origin)
Travel Time (s)	t_t	20	Travel to open stairway
Travel Time (s)	t_t	29	Travel to outside through enclosed stairway
Travel Time (s)	t_t	64	Travel to outside through retail area
Queuing Time (s)	t_q	22	Queuing at open stairway
Queuing Time (s)	t_q	22	Queuing at enclosed stairway on ground floor
Queuing Time (s)	t_q	246	Queuing at retail area
RSET (s) – Clear mezzanine to open stairway		154	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 72+60+22=154
RSET (s) – Clear mezzanine to the outside through enclosed stairway		161	Queuing time is not included in the RSET because the travel time is dominant (Occupants are travelling rather than queuing) 72+60+29=161
RSET (s) – Clear mezzanine to the outside through retail area		378	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 72+60+246=378

Table 4-9: Required inputs to determine the evacuation time for mezzanine fire

FIRE LOCATED IN MEZZANINE (MEZZANINE FIRE)			
Component		**Value**	**Remark**
Detection Time (s)	t_d	139	Sprinkler activation time
Retail Area			
Pre-movement Time (s)	t_p	120	The occupants are awake and unfamiliar with the building (remote from the room of fire origin)
Travel Time (s)	t_t	28	Travel to outside
Queuing Time (s)	t_q	246	Clear occupants to outside
RSET (s) – Clear retail area		505	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 139+120+246=505
Storage Area			
Pre-movement Time (s)	t_p	60	The occupants are awake and familiar with the building (remote from the room of fire origin)
Travel Time (s)	t_t	23	Travel to outside
Travel Time (s)	t_t	24	Travel to stairway
Queuing Time (s)	t_q	9	Clear occupants to outside
Queuing Time (s)	t_q	22	Clear occupants to stairway
RSET (s) – Clear storage area to outside		222	Queuing time is not included in the RSET because the travel time is dominant (Occupants are travelling rather than queuing) 139+60+23=222
RSET (s) – Clear storage area to the outside through stairway		223	Queuing time is not included in the RSET because the travel time is dominant (Occupants are travelling rather than queuing) 139+60+24=223
Drive Thru Area			
Pre-movement Time (s)	t_p	120	The occupants are awake and unfamiliar with the building (remote from the room of fire origin)
Travel Time (s)	t_t	20	Travel to outside
Queuing Time (s)	t_q	11	Clear occupants to outside
RSET (s) – The last occupant to clear the building		279	Queuing time is not included in the RSET because the travel time is dominant (Occupants are travelling rather than queuing) 139+120+20=279

MEZZANINE (ROOM OF FIRE ORIGIN)			
Pre-movement Time (s)	t_p	30	The occupants are awake and familiar with the building (Room of fire origin)
Travel Time (s)	t_t	20	Travel to open stairway
Travel Time (s)	t_t	29	Travel to outside through enclosed stairway
Travel Time (s)	t_t	64	Travel to outside through retail area
Queuing Time (s)	t_q	22	Queuing at open stairway
Queuing Time (s)	t_q	22	Queuing at enclosed stairway on ground floor
Queuing Time (s)	t_q	246	Queuing at retail area
RSET (s) – Clear mezzanine to open stairway		191	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 139+30+22=191
RSET (s) – Clear mezzanine to the outside through enclosed stairway		198	Queuing time is not included in the RSET because the travel time is dominant (Occupants are travelling rather than queuing) 139+30+29=198
RSET (s) – Clear mezzanine to the outside through retail area		415	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 139+30+246=415

4.3.5 ASET and RSET Analysis

The results of ASET and RSET were determined in section 4.3.3 and calculated in section 4.3.4 respectively. The performance objective of DFS1 is to "provide a tenable environment for occupants in the event of a fire while they escape to a safe place"[1]. In order to determine occupants can evacuate to a safe place, the values of ASET and RSET were compared. ASET shall be greater than RSET to demonstrate compliant with the DFS1. A summary of ASET and RSET for the retail fire, storage fire, drive thru fire and mezzanine fire are provided in Table 4-10.

Table 4-10: ASET and RSET for retail warehouse

FIRE LOCATED IN RETAIL AREA (RETAIL FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Retail Area	741	383	358	193	Comply
Retail Area	741	383[a]	358	193	Comply
Stock Room	523	160	363	327	Comply
Drive Thru	1610	217	1390	742	Comply
Stairway	> 1800	161[b]	> 1638	> 1120	Comply
Stairway	> 1800	166[c]	> 1633	> 1080	Comply
Mezzanine	> 1800	159	> 1641	> 1130	Comply
FIRE LOCATED IN STORARE AREA (STORAGE FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Retail Area	1180	436	744	271	Comply
Retail Area	1180	376[a]	808	315	Comply
Stock Room	346	123	223	281	Comply
Drive Thru	> 1800	210	> 1590	> 857	Comply
Stairway	897	124[b]	773	723	Comply
Stairway	897	159[c]	738	564	Comply
Mezzanine	> 1800	152	> 1650	> 1180	Comply
FIRE LOCATED IN DRIVE THRU (DRIVE THRU FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Retail Area	1730	438	1290	394	Comply
Retail Area	1730	378[a]	1350	456	Comply
Stock Room	> 1800	155	> 1650	> 1160	Comply
Drive Thru	290	152	138	191	Comply
Stairway	> 1800	156[b]	> 1640	> 1150	Comply
Stairway	> 1800	161[c]	> 1640	> 1120	Comply
Mezzanine	> 1800	154	> 1650	> 1170	Comply
FIRE LOCATED IN MEZZANINE (MEZZANINE FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Retail Area	> 1800	505	> 1285	> 354	Comply
Retail Area	> 1800	415[a]	> 1377	> 432	Comply
Stock Room	> 1800	222	> 1578	> 811	Comply
Drive Thru	> 1800	279	> 1521	> 645	Comply
Stairway	1216	223[b]	993	545	Comply
Stairway	1216	198[c]	1018	614	Comply
Mezzanine	896	191	705	469	Comply

Note a: Occupants in mezzanine travelled to the retail area through the open stairway to the outside

Note b: Occupants in the storage area to clear the building through the enclosed stairway

Note c: Occupants in the mezzanine to clear the building through the enclosed stairway

4.3.6 Conclusion of Design Fire Scenario One (Challenging Fire)

The analysis using the fire modelling rules undertaken in BRANZFIRE showed that all occupants in the retail warehouse had sufficient time to make their escape before the untenable condition occurred. The results of DFS1 were summarised in Table 4-11 and it showed that the retail warehouse achieved DFS1.

Table 4-11: Summary of DFS1 in retail warehouse

Output	Retail Fire		Storage Fire		Drive Thru Fire		Mezzanine Fire	
	Retail	Stairway	Storage	Stairway	Drive	Stairway	Mezz	Stairway
ASET (s)	741	> 1800	346	897	290	> 1800	896	1216
RSET (s)	383	169	123	162	152	164	191	201
Margin (s)	358	> 1630	223	735	138	> 1635	705	1015
Margin (%)	193%	> 1060%	281%	554%	191%	> 1100%	469%	605%
Scenario Result	Comply	Comply	Comply	Comply	Comply	Comply	Comply	Comply

4.4 Design Fire Scenario Two (Blocked Exit)

This scenario addressed the concern for single means of egress that serves more than 50 people. Each area in the building was provided more than one escape route of equal or greater size. Design Fire Scenario Two was achieved.

4.5 Design Fire Scenario Three (Fire in Unoccupied Room)

The building was protected by an automatic sprinkler system and the system was installed in accordance with NFPA13 [27]. Design Fire Scenario Three was achieved.

4.6 Design Fire Scenario Four (Concealed Space)

The building was protected by an automatic sprinkler system and the system was installed in accordance with NFPA13 [27]. Design Fire Scenario Four was achieved.

4.7 Design Fire Scenario Five (Smouldering Fire)

This scenario addressed the concern for sleeping occupants. The building was not designed for sleeping purpose, therefore there was no requirement to test this scenario in this building and Design Fire Scenario Five was achieved.

4.8 Design Fire Scenario Six (Spread to Other Property)

The west wall was 0.1 m to the relevant boundary, and the north wall, east wall and south wall was 7.0 m, 22.0 m and 30.0 m to the relevant boundary. The west exterior wall was fire rated and the other walls were not fire rated in accordance with NFPA5000. To comply with Design Fire Scenario Six, the building must satisfy the requirements of Part 7 of C/AS1.

The building was 8.0 m height and the north wall was 40.0 m width. Sprinkler system was installed throughout in the building and the building contains bulk storage of combustible materials over 3 m high. The building was classified as Purpose Group WF and contains Fire Hazard Category 4 materials as per C/AS1 Table 2.1. According to C/AS1 Table 7.2/6 and Clause 7.3.12 [2], the west wall was only allowed 48% unprotected area. The west wall was 100% unprotected and therefore Design Fire Scenario Six was not achieved.

4.9 Design Fire Scenario Seven (Vertical External Fire Spread)

The building did not contain sleeping occupancies and the building height was less than 10 m. The building was sprinklered protected to prevent external fire spread between floors via the exterior openings and the exterior walls were constructed of non-combustible concrete to reduce the probability of vertical fire spread over the surface of an exterior cladding. Therefore, the building did not require testing in this scenario and Design Fire Scenario Seven is achieved.

4.10 Design Fire Scenario Eight (Interior Surface Finishes)

NFPA5000 regulated interior finish materials based upon flame spread, smoke production, and occupancy of the area. ASTM E-84 [28] was the principal test method used by NFPA5000 to characterise flame spread and smoke production. NFPA286 [29] also allowed for large scale testing of interior finishes.

The objective of this scenario was to maintain tenable conditions on escape routes while occupants were evacuating and to prevent rapid fire spread that could compromise the retreat of firefighters. Performance criteria for lining materials depended on their location in the building and the occupancy type. Sprinkler system was installed throughout the building and therefore the smoke production rate criteria were not required to be tested. The interior finish material in the building was gypsum plasterboard and achieved a time to flashover not less than 20 minutes under test conditions of ISO 9705 [30]. The interior finish material in the stairway was non-combustible concrete and achieved a time to flashover not less than 20 minutes under test conditions of ISO 9705 [30]. The building achieved Design Fire Scenario Eight.

4.11 Design Fire Scenario Nine (Fire Service Operations)

The objective of this scenario was to facilitate firefighters operation and avoid unexpected collapse that would endanger fire service personnel within or near to the building. The area of the building was greater than 1500 m^2 and contained Fire Hazard Category 4 materials. Water from street hydrants was available via a pumping appliance parked closed to the building. Any point within the building was reached within 75 m and was protected by sprinkler system, therefore it was not necessary to demonstrate firefighter tenability for heat and smoked exposure.

Structural stability criteria for firefighters were not achieved because there was no safe path access to the intermediate floor and the intermediate floor was not fire rated. The building not achieved Design Fire Scenario Nine.

4.12 Design Fire Scenario Ten (Robustness Check)

This scenario only applied to areas with more than 150 people or more than 6 people in sleeping care occupancy. The robustness of the design was tested by considering the design fire with each key fire safety system rendered ineffective in turn excluding fire sprinkler system installed to a recognised standard. There were more than 150 people in the retail area but the area did not contain smoke management systems, fire/smoke doors or walls. There was no requirement to test this scenario in this building and Design Fire Scenario Ten was achieved.

4.13 Summary for Case Study Building One (Retail Warehouse)

Ten design fire scenarios were applied to the building. The building did not meet the performance measure of the framework because it failed to achieve the DFS6 and DFS9. A summary of DFS1 to DFS10 in the retail warehouse is provided in Table 4-12.

Table 4-12: Summary of design fire scenarios in the retail warehouse

Design Fire Scenario	Result for the retail warehouse
DSF1: Challenging Fire	Comply
DSF2: Block Exit	Comply
DSF3: Fire in Unoccupied Spaces	Comply
DSF4: Fire in Concealed Spaces	Comply
DSF5: Smouldering Fire	Comply
DSF6: Spread to Other Property	Not Comply
DSF7: Vertical External Fire Spread	Comply
DSF8: Interior Surface Finishes	Comply
DSF9: Fire Service Operations	Not Comply
DSF10: Robustness Check	Comply

5 Case Study Building Two (Hospital)

5.1 Building Description

The building is a four storeys hospital providing sleeping accommodations for their occupants. The occupants are mostly suffering from physical or mental disability and may not be capable of self-preservation. The building is occupied on a 24 hour basis for the occupants throughout the year and staffs are required to intervene in fire safety functions in all patient-occupied area.

Floor 1 is mainly for outpatients. Floors 2 to 4 contain inpatients and staffs and they can access to lower floors through stairways and lifts. The overall building is 104 m wide, 102 m long and 9.6 m height. Each floor has floor to floor height of 2.4 m. The West wall is 20 m to the relevant boundary, the North wall is 15 m to the relevant boundary, the East wall is 20 m to the relevant boundary and the South wall is 50 m to the relevant boundary. The activities within the building are summarised in Table 5-1 and the building layouts are provided in Figure 5-1, Figure 5-2, Figure 5-3 and Figure 5-4.

Table 5-1: Description of hospital

Floor	Activities	Detail
1	Kitchen, cafeteria, storage areas, gift shop, emergency area, admitting, outpatient service, physiotherapy and business offices	Outpatients and staffs
2	Laboratory, storage area, surgical suits and sleeping suits	Inpatients and staffs
3	Staff residential areas, cancer centre, ICU and sleeping suits	Inpatients and staffs
4	Psychiatric units, Social work and sleeping suits	Inpatients and staffs

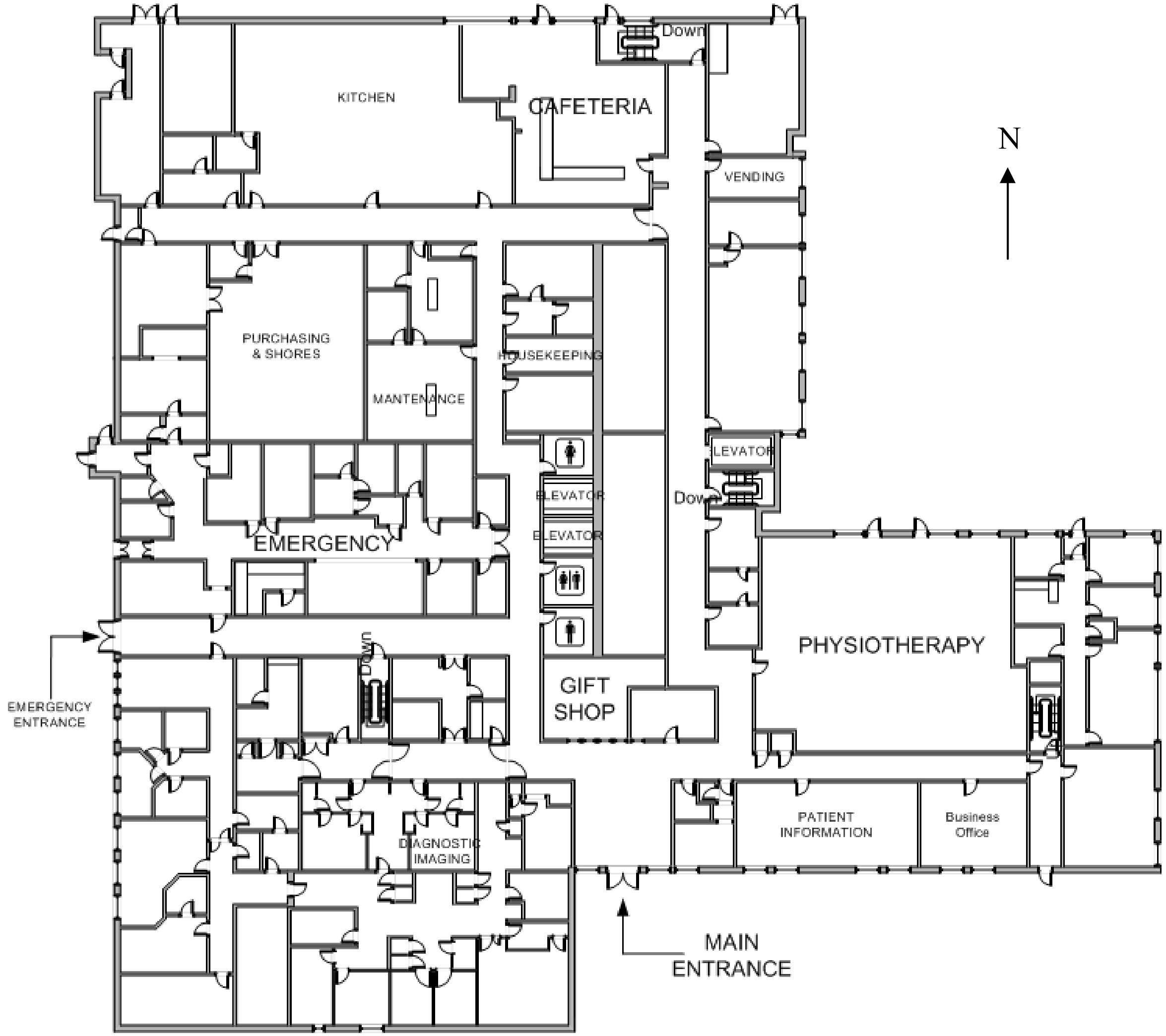

Figure 5-1: Plan view of floor 1 in hospital (not to scale)

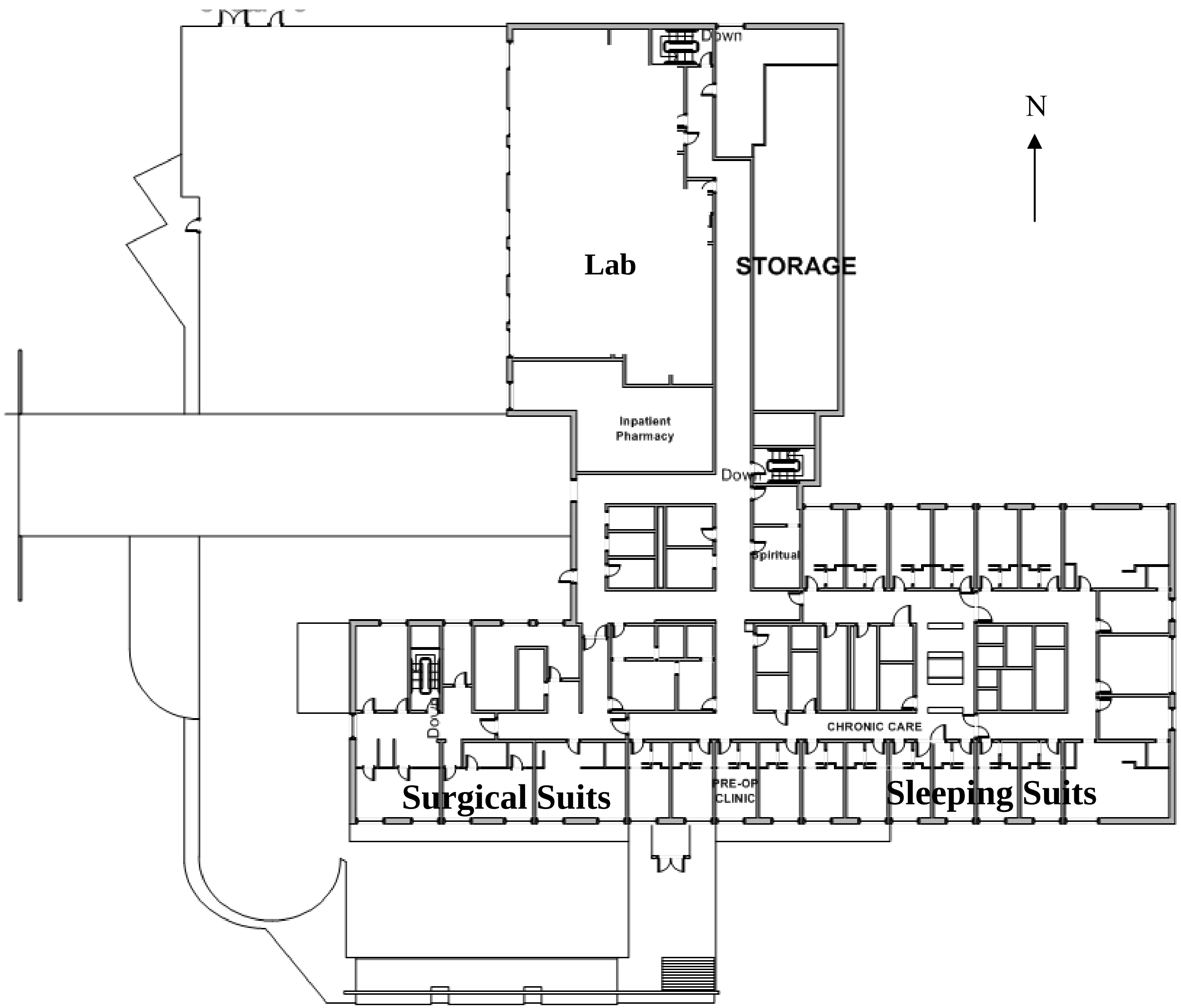

Figure 5-2: Plan view of floor 2 in hospital (not to scale)

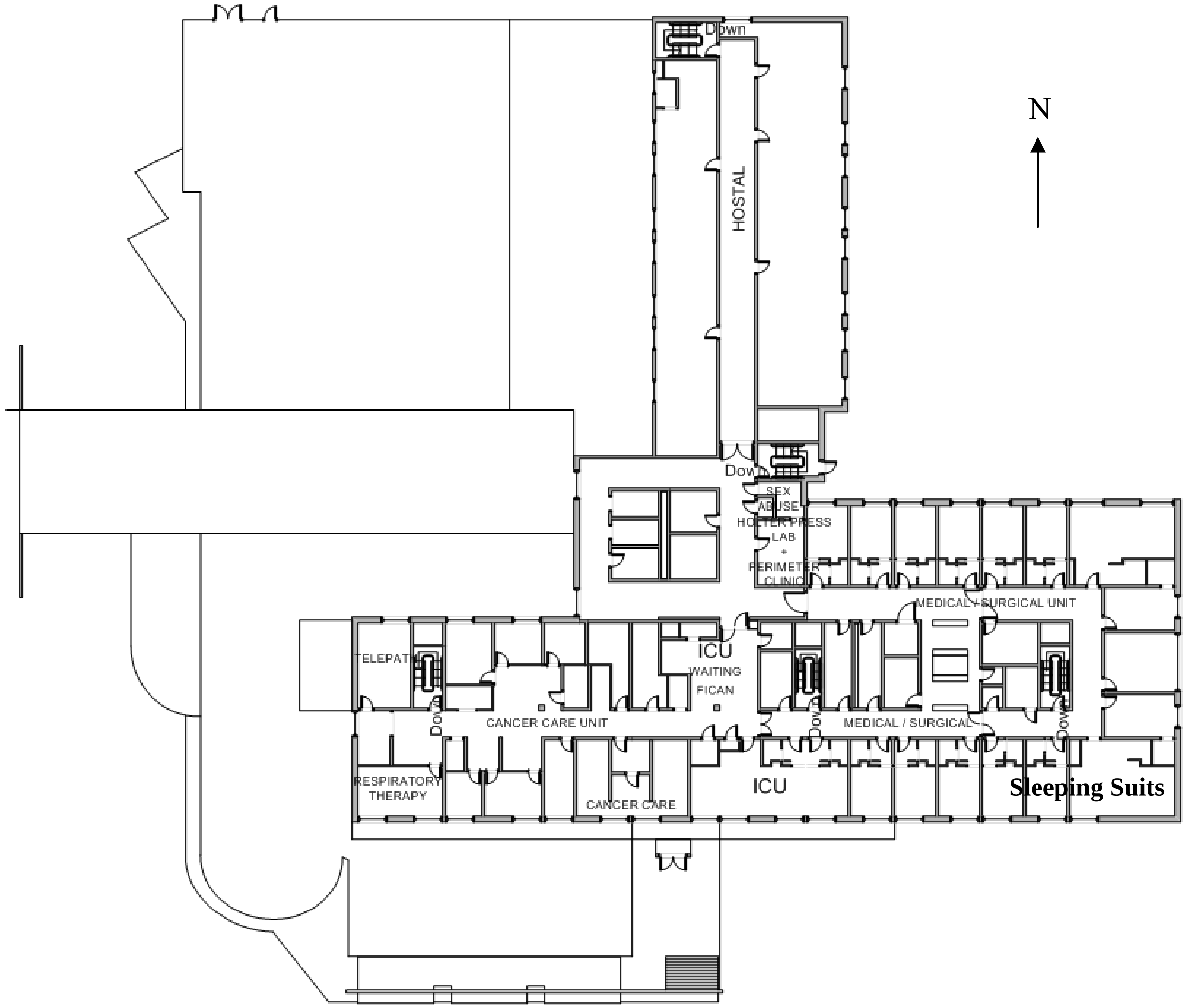

Figure 5-3: Plan view of floor 3 in hospital (not to scale)

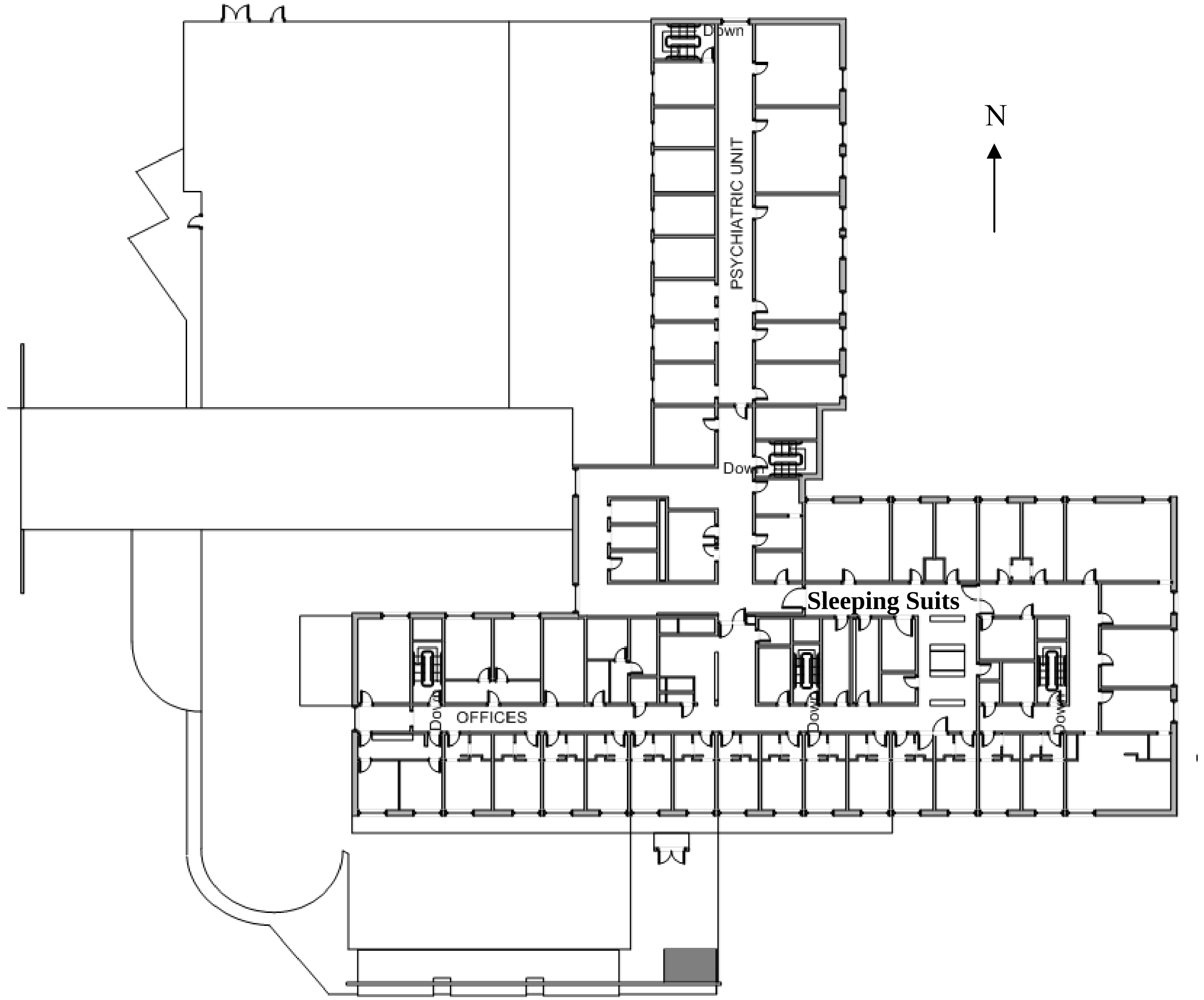

Figure 5-4: Plan view of floor 4 in hospital (not to scale)

5.2 NFPA5000 Audit

The building will satisfy the prescriptive requirement of the NFPA5000 if the following fire requirements are implemented. A detailed NFPA5000 audit report including building layouts, relevant boundaries, occupancy types, occupant loads, required fire protection systems and exits and egress routes can be found in Appendix A2.

- The building is protected by an approved, electrically supervised automatic sprinkler system in accordance with NFPA13
- Quick-response sprinklers are installed throughout smoke compartments containing sleeping patient
- Sleeping areas, waiting areas and staff residential areas are protected by an electrically supervised automatic smoke detection system
- Gas cylinder storage room, kitchen, cafeteria, storage rooms, retail shop, emergency area and staff residential areas are fire separated from the other areas
- Floors 2 to 4 are subdivided into three smoke compartments
- Single means of egress is not permitted in the building. Each area is provided at least two means of egress and is satisfied with the accessible means of egress requirements
- All interior enclosed stairways are constructed as a smoke and 2 hours fire barrier
- The minimum 1.12 m clear stair width for discharge from a stairway has been achieved. The tread depth and the riser height of the stairs are 0.3 m and 0.15 m respectively
- All fire rated doors and smoke doors are installed with self-closing devices

5.3 Design Fire Scenario One (Challenging Fire)

The framework defines a set of design fire scenarios to evaluate the case study building. The first design fire scenario is DFS1 which provides a credible worst case scenario to challenge the fire protection features of the building. In this scenario, occupancy-specific design fires locate in several places within the building with all fire safety systems working as intended.

5.3.1 Description of Fire Modelling in BRANZFIRE

5.3.1.1 Cafeteria Fire

The cafeteria, adjacent stairway, corridors and foyer were modelled in BRANZFIRE (Figure 5-5). The room dimensions are shown in Table 5-2. Windows and a number vents were connected between rooms or between room and the outside of the building in accordance with the fire modelling rules in section 2.6. Table 5-2 provides the detail of the vents used in BRANZFIRE between compartments and to the outside. Construction materials for walls, floors and ceilings in each room modelled in BRANZFIRE are shown in Table 5-4.

Table 5-2: Summary of room dimensions included in BRANZFIRE modelling for cafeteria fire

Room	Width (m)	Length (m)	Height (m)	Floor Height (m)
(1) Cafeteria	14	20	2.4	0.0
(2) Corridor-1	54	3.6	2.4	0.0
(3) Corridor-2	3.6	88.6	2.4	0.0
(4) Corridor-3	3.6	49.5	2.4	0.0
(5) Foyer	22.6	12.0	2.4	0.0
(6) Stairway	3.4	7.0	9.6	0.0

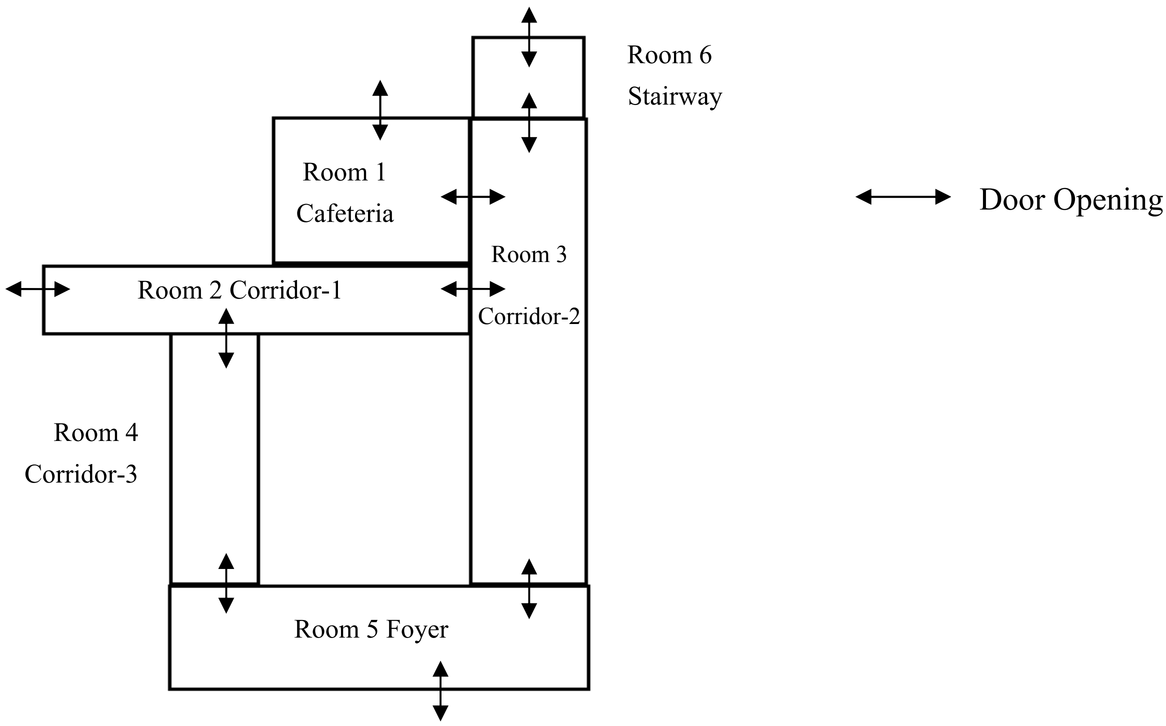

Figure 5-5: BRANZFIRE modelling for cafeteria fire

Table 5-3: Summary of vent dimensions connecting rooms included in BRANZFIRE modelling for cafeteria fire

Room	Vent width (m)	Vent height (m)	Sill Height (m)	Opening Time (s)	Closing Time (s)	Function
Cafeteria to outside	0.81	2.03	0	Always	None	Door
Cafeteria to Corridor-2	1.62	0.01	2.03	Always	None	Leakage
Corridor-1 to Corridor-2	3.6	2.4	0	Always	None	Opening
Corridor-1 to Corridor-3	3.6	2.4	0	Always	None	Opening
Corridor-1 to Outside	0.4	2.03	0	Always	None	Door
Corridor-2 to Foyer	3.6	2.4	0	Always	None	Opening
Corridor-2 to stairway	0.4	2.03	0	Detection	+ 54	Door
Corridor-3 to Foyer	3.6	2.4	0	Always	None	Opening
Foyer to Outside	0.5	2.03	0	Always	None	Door
Stair to Outside	0.4	2.03	0	Always	None	Door

Table 5-4: Summary of surface, material and substrate for various rooms in BRANZFIRE modelling in hospital

Room	Wall Material	Ceiling Material	Floor Material
	Surface	Surface	Surface
All rooms	Concrete	Concrete	Concrete

5.3.1.1 Physiotherapy Fire

The physiotherapy, stairway, corridors and foyer were modelled in BRANZFIRE (Figure 5-6). The room dimensions are shown in Table 5-5. Table 5-6 provides the detail of the vents used in BRANZFIRE between compartments and to the outside. Construction materials for walls, floors and ceilings in each room modelled in BRANZFIRE are shown in Table 5-4.

Table 5-5: Summary of room dimensions included in BRANZFIRE modelling for physiotherapy fire

Room	Width (m)	Length (m)	Height (m)	Floor Height (m)
(1) Physiotherapy	23.6	26.5	2.4	0.0
(2) Corridor-2	3.6	88.6	2.4	0.0
(3) Foyer	22.6	12.0	2.4	0.0
(4) Corridor-3	3.6	49.5	2.4	0.0
(5) Corridor-1	54	3.6	2.4	0.0
(6) Stairway	3.4	7.0	9.6	0.0

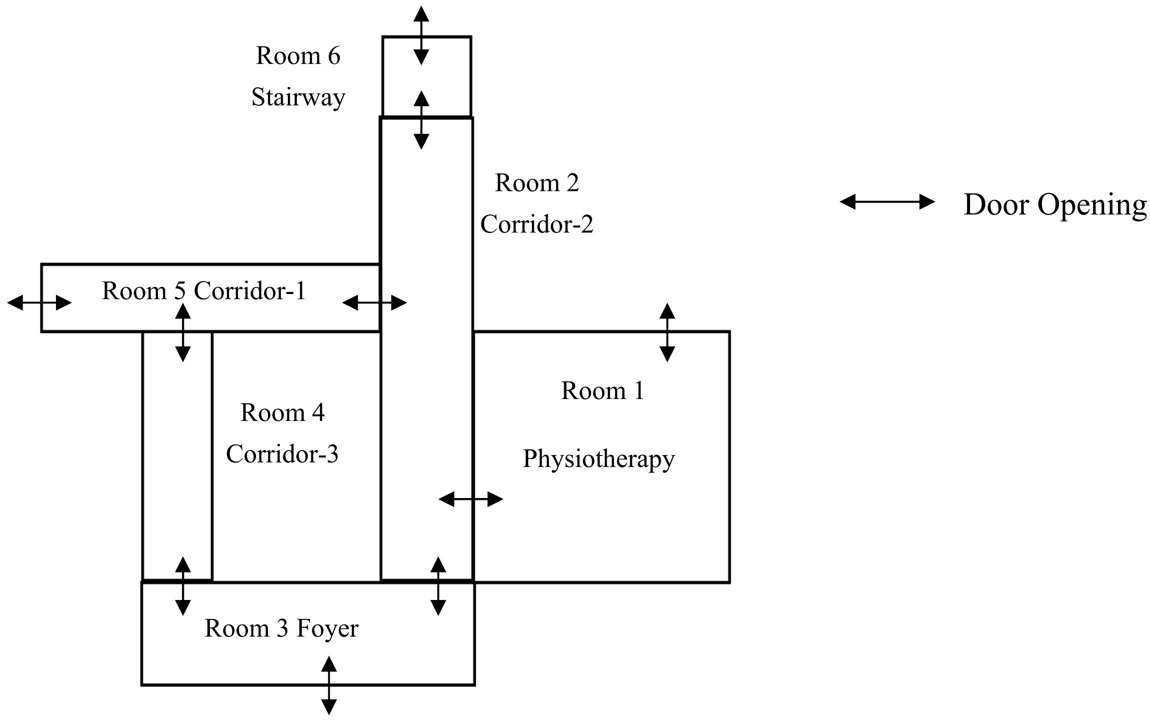

Figure 5-6: BRANZFIRE modelling for physiotherapy fire

Table 5-6: Summary of vent dimensions connecting rooms included in BRANZFIRE modelling for physiotherapy fire

Room	Vent width (m)	Vent height (m)	Sill Height (m)	Opening Time (s)	Closing Time (s)	Function
Physiotherapy to Outside	0.4	2.03	0	Always	None	Door
Physiotherapy to Corridor-2	0.4	2.03	0	Always	None	Door
Corridor-2 to Foyer	3.6	2.4	0	Always	None	Opening
Corridor-2 to Corridor-1	3.6	2.4	0	Always	None	Opening
Corridor-2 to Stair	0.4	2.03	0	Detection	+ 54	Door
Foyer to Corridor-3	3.6	2.4	0	Always	None	Opening
Foyer to Outside	0.5	2.03	0	Always	None	Door
Corridor-3 to Corridor-1	3.6	2.4	0	Always	None	Opening
Corridor-1 to Outside	0.4	2.03	0	Always	None	Door
Stair to Outside	0.4	2.03	0	Always	None	Door

5.3.1.1 Laboratory Fire

The laboratory, stairway and corridors were modelled in BRANZFIRE (Figure 5-7). The room dimensions are shown in Table 5-7. Windows and a number vents are connected between rooms or between room and the outside of the building in accordance with the fire modelling rules in section 2.6. Table 5-8 provides the detail of the vents used in BRANZFIRE between compartments and to the outside. Construction materials for walls, floors and ceilings in each room modelled in BRANZFIRE are shown in Table 5-4.

Table 5-7: Summary of room dimensions included in BRANZFIRE modelling for laboratory fire

Room	Width (m)	Depth (m)	Height (m)	Floor Height (m)
(1) Laboratory	23.0	39.0	2.4	2.4
(2) Corridor-1	3.4	33.2	2.4	2.4
(3) Stairway	7.0	3.4	9.6	0
(4) Corridor-2	10.5	26.0	2.4	2.4

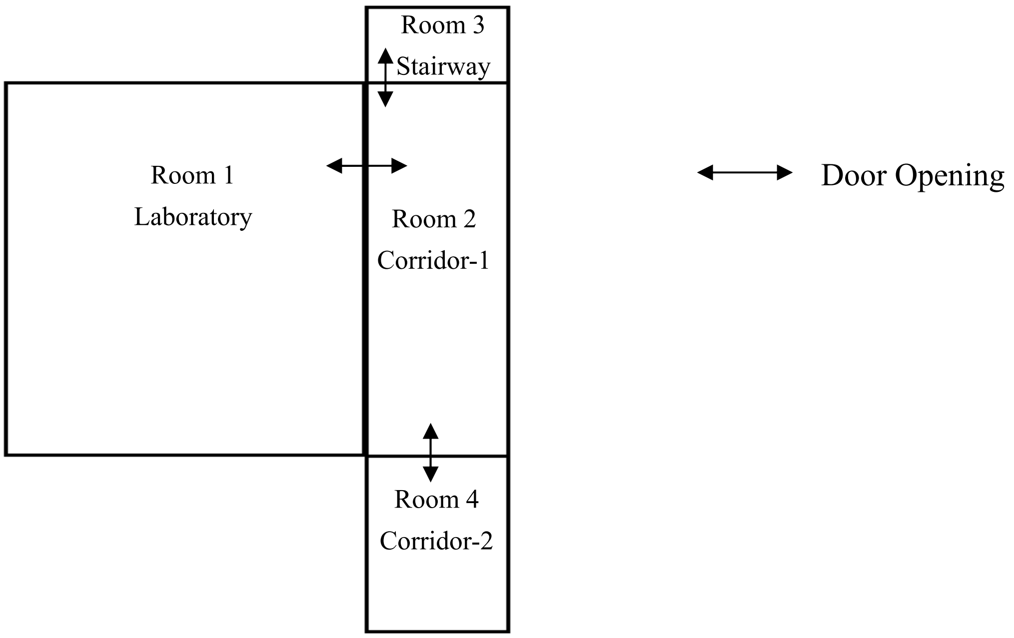

Figure 5-7: BRANZFIRE modelling for laboratory fire

Table 5-8: Summary of vent dimensions connecting rooms included in BRANZFIRE modelling for laboratory fire

Room	Vent width (m)	Vent height (m)	Sill Height (m)	Opening Time (s)	Closing Time (s)	Function
Laboratory to Corridor-1	1.6	0.01	2.03	Always	None	Leakage
Laboratory to Corridor-1	0.8	2.03	0	Detection	+ 72	Door
Corridor-1 to Corridor-2	1.1	2.03	0	Detection	+ 81	Door
Corridor-1 to Stairway	0.4	2.03	0	Detection	+ 81	Door

5.3.1.1 Hostel Fire

The hostel, stairway and corridors were modelled in BRANZFIRE (Figure 5-8). The room dimensions are shown in Table 5-9. Windows and a number vents were connected between rooms or between room and the outside of the building in accordance with the fire modelling rules in section 2.6.

Table 5-10 provides the detail of the vents used in BRANZFIRE between compartments and to the outside. Construction materials for walls, floors and ceilings in each room modelled in BRANZFIRE are shown in Table 5-4.

Table 5-9: Summary of room dimensions included in BRANZFIRE modelling for hostel fire

Room	Width (m)	Depth (m)	Height (m)	Floor Height (m)
(1) Hostel	10.0	44.8	2.4	4.8
(2) Corridor-1	3.2	48.0	2.4	4.8
(3) Stairway	7.0	3.4	9.6	0
(4) Corridor-2	12.6	31.0	2.4	4.8

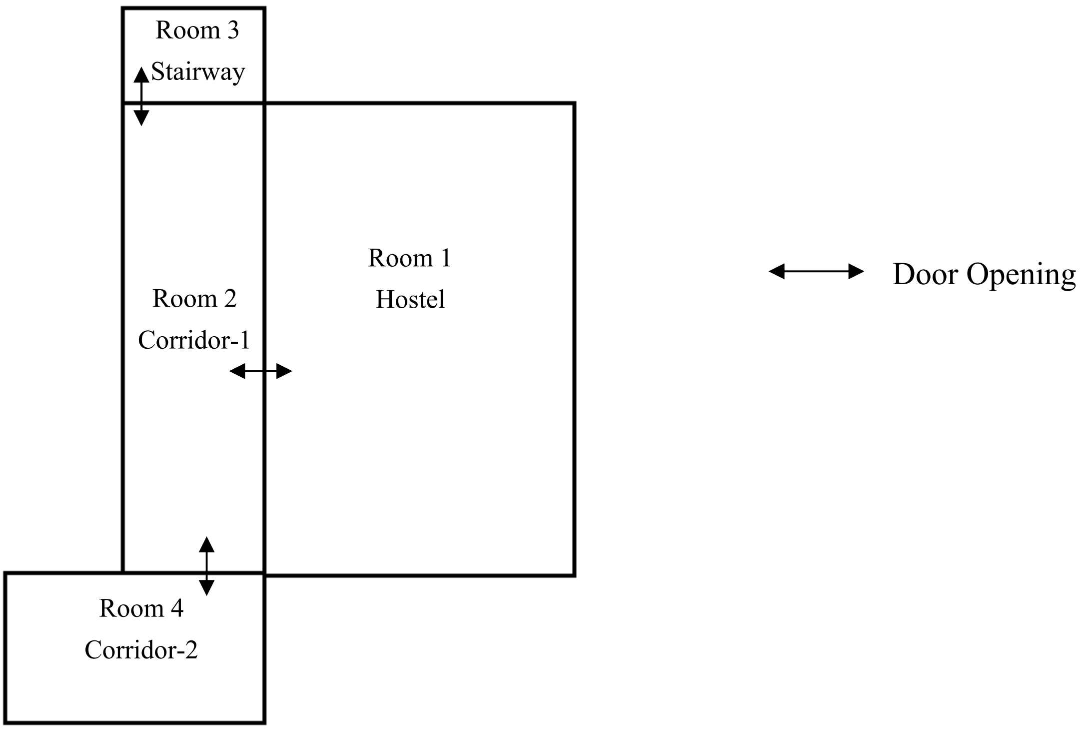

Figure 5-8: BRANZFIRE modelling for hostel fire

Table 5-10: Summary of vent dimensions connecting rooms included in BRANZFIRE modelling for hostel fire

Room	Vent width (m)	Vent height (m)	Sill Height (m)	Opening Time (s)	Closing Time (s)	Function
Hostel to Corridor-1	1.6	0.01	2.03	Always	None	Leakage
Hostel to Corridor-1	0.8	2.03	0	Detection	+ 18	Door
Corridor-1 to Corridor-2	1.1	2.03	0	Detection	+ 32	Door
Corridor-1 to Corridor-2	2.1	0.01	2.03	Always	None	Leakage
Corridor-1 to Stairway	0.4	2.03	0	Detection	+ 32	Door

5.3.2 Design Fire

The area of cafeteria, physiotherapy, laboratory and hostel were greater than 200 m^2 and were required to be analysed under Design Fire Scenario One. The design fire growth rates in different areas and the peak heat release rate from BRANZFIRE modelling are detailed in Table 5-11. The design fire in all areas was assumed to grow as fast t^2.

Windows in the cafeteria fire and physiotherapy were not broken as the upper temperature was not reached 500 ^oC, or the heat release rate was not reduced after the fire reached peak heat release rate. Heat release rate was reduced after 2376 s and after 1979 s in laboratory fire and hostel fire. Therefore, it was decided to manually break all the windows in the laboratory and the hostel at 2376 s and 1979 s respectively as required by the modelling rules specified in the framework.

Table 5-11: Design fire used in BRANZFIRE modelling for hospital

Fire Location	Fire Growth Rate (kW)	Time to reach 500^{o}C or when the Heat Release Rate reduces (s)	Peak Heat Release Rate (MW) from BRANZFIRE Modelling
Cafeteria	$0.047t^2$	Not reach	0.9
Physiotherapy	$0.047t^2$	640	1.1
Laboratory	$0.047t^2$	2380	1.2
Hostel	$0.047t^2$	1990	0.7

Soot and carbon monoxide production rate used in the BRANZFIRE modelling are listed below:

- Pre-flashover species yield for soot (Y_{soot}) was 0.07 kg/kg

- Pre-flashover species yield for carbon monoxide (Y_{co}) was 0.04 kg/kg
- Post-flashover species yield for soot (Y_{soot}) was 0.14 kg/kg
- Post-flashover species yield for carbon monoxide (Y_{soot}) was 0.40 kg/kg

5.3.3 BRANZFIRE Modelling Results to determine ASET

The fire modelling rules of the framework required some way to alert the occupants. An automatic sprinkler system was required from NFPA5000 and is installed throughout the building in order to control and suppress the fire as well as to alert the occupants. A quick response sprinkler system and smoke detection system were installed in the hostel area and sleeping area. All other areas were protected with standard response sprinkler system. Sprinkler system was installed throughout the building therefore the criterion for occupant tenability was based on FED for carbon monoxide. The BRANZFIRE results for fire located in cafeteria, physiotherapy, laboratory and hostel are summarized in Table 5-12.

Table 5-12: BRANZFIRE results DFS1 for hospital

FIRE LOCATED IN CAFETERIA (CAFERTERIA FIRE)			
Room	**Visibility (10m)**	**FED (Thermal)**	**FED(CO)**
Cafeteria	96s	258s	881s
Corridor-1	6180s	> 7200s	6480s
Corridor-2	> 7200s	> 7200s	> 7200s
Corridor-3	> 7200s	> 7200s	> 7200s
Foyer	> 7200s	> 7200s	> 7200s
FIRE LOCATED IN PHYSIOTHERAPY (PHYSIOTHERAPY FIRE)			
Room	**Visibility (10m)**	**FED (Thermal)**	**FED(CO)**
Physiotherapy	143s	454s	1140s
Corridor-2	388s	> 7200s	2960s
Foyer	629s	> 7200s	3600s
Corridor-3	869s	> 7200s	4130s
Corridor-1	574s	> 7200s	3490s
Stairway	> 7200s	> 7200s	> 7200s
FIRE LOCATED IN LABORATORY (LABORATORY FIRE)			
Room	**Visibility (10m)**	**FED (Thermal)**	**FED(CO)**
Laboratory	632s	170s	1080s
Corridor-1	> 7200s	> 7200s	1990s
Corridor-2	> 7200s	> 7200s	> 7200s
Stairway	> 7200s	> 7200s	> 7200s

FIRE LOCATED IN HOSTEL (HOSTEL FIRE)			
Room	**Visibility (10m)**	**FED (Thermal)**	**FED(CO)**
Hostel	122s	545s	916s
Corridor-1	> 7170s	> 7170s	1850s
Corridor-2	> 7170s	> 7170s	> 7170s
Stairway	> 7170s	> 7170s	> 7170s
Mezzanine	96s	270s	875s

5.3.4 RSET Calculations

The occupants on ground floor are assumed to be awake and unfamiliar with the building, except the staffs are assumed to be familiar with the escape routes. The areas in the upper floors are mainly for patient care purposes and they are assumed to be asleep and unfamiliar with the building whilst the staffs in the laboratory are assumed to be awake and familiar with the escape routes. The calculations of RSET were explained in section 2.5. RSET is a sum of detection time, pre-movement time, and travel time or queuing time. A summary of evacuation time for the hospital are provided in Table 5-13 to Table 5-16 and Appendix B.

Table 5-13: Required inputs to determine the evacuation time for cafeteria fire

FIRE LOCATED IN CAFETERIA (CAFETERIA FIRE)			
Component		**Value**	**Remark**
Detection Time (s)	t_d	141	Sprinkler activation time
CAFETERIA (ROOM OF FIRE ORIGIN)			
Pre-movement Time (s)	t_p	60	The occupants are awake and unfamiliar with the building (Room of fire origin)
Travel Time (s)	t_t	27	Travel to the outside of building
Queuing Time (s)	t_q	239	Clear occupants to the outside of building
RSET (s) – Cafeteria Occupants to clear the building		440	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 141+60+239=440
Emergency (The last occupant on floor 1 to clear the building)			
Pre-movement Time (s)	t_p	120	The occupants are awake and unfamiliar with the building (remote from the room of fire origin)
Travel Time (s)	t_t	62	Travel to the outside of building
Queuing Time (s)	t_q	241	Clear occupants to the outside of building
RSET (s) – The last occupant on floor 1 to clear the building		502	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 141+120+241=502
Sleeping occupants on Floor 4 (The last occupant in the building to clear the building)			
Pre-movement Time (s)	t_p	1800	The occupants are asleep and under the care of trained staff (remote from the room of fire origin)
Travel Time (s)	t_t	53	Travel to the nearest exit
Queuing Time (s)	t_q	171	Clear occupants above the first floor
RSET (s) – The last occupant to clear the building		2131	Required safety egress time for the last occupant in the building 141+1800+171=2131

Table 5-14: Required inputs to determine the evacuation time for physiotherapy fire

FIRE LOCATED IN PHYSIOTHERAPY (PHYSIOTHERAPY FIRE)			
Component		**Value**	**Remark**
Detection Time (s)	t_d	153	Sprinkler activation time
PHYSIOTHERAPY (ROOM OF FIRE ORIGIN)			
Pre-movement Time (s)	t_p	60	The occupants are awake and unfamiliar with the building (remote from the room of fire origin)
Travel Time (s)	t_t	28	Clear physiotherapy to corridor
Travel Time (s)	t_t	56	Clear physiotherapy to the outside of building
Queuing Time (s)	t_q	51	Clear physiotherapy to corridor
Queuing Time (s)	t_q	241	Clear physiotherapy to the outside of building
RSET (s) – Occupants clear physiotherapy to corridor		264	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 153+60+51=264
RSET (s) – Physiotherapy occupants to clear floor 1		454	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 153+60+241=454
Emergency (The last occupant on floor 1 to clear the building)			
Pre-movement Time (s)	t_p	120	The occupants are awake and under the care of trained staff (remote from the room of fire origin)
Travel Time (s)	t_t	62	Travel to the outside of building
Queuing Time (s)	t_q	241	Clear occupants to the outside of building
RSET (s) – The last occupant on floor 1 to clear the building		514	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 153+120+241=514
Sleeping occupants on Floor 4 (The last occupant in the building to clear the building)			
Pre-movement Time (s)	t_p	1800	The occupants are asleep and under the care of trained staff (remote from the room of fire origin)
Travel Time (s)	t_t	53	Travel to the nearest exit
Queuing Time (s)	t_q	171	Clear occupants above the first floor
RSET (s) – The last occupant to clear the building		2124	Required safety egress time for the last occupant in the building 153+1800+171=2124

Table 5-15: Required inputs to determine the evacuation time for laboratory fire

FIRE LOCATED IN LABORATORY (LABORATORY FIRE)			
Component		**Value**	**Remark**
Detection Time (s)	t_d	160	Sprinkler activation time
LABORATORY (ROOM OF FIRE ORIGIN)			
Pre-movement Time (s)	t_p	30	The occupants are awake and familiar with the building (remote from the room of fire origin)
Travel Time (s)	t_t	28	Clear laboratory to corridor
Travel Time (s)	t_t	49	Clear laboratory to a stairway
Queuing Time (s)	t_q	72	Clear laboratory to corridor
Queuing Time (s)	t_q	89	Clear laboratory to a stairway
RSET (s) – Occupants clear laboratory		262	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 160+30+72=262
RSET (s) – Laboratory occupants to clear floor 2		279	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 160+30+89=279
Sleeping occupants (The last occupant on floor 2 to clear floor 2)			
Pre-movement Time (s)	t_p	1800	The occupants are asleep and under the care of trained staff (remote from the room of fire origin)
Travel Time (s)	t_t	47	Travel to a stairway
Queuing Time (s)	t_q	60	Clear occupants to a stairway
RSET (s) – The last occupant on floor 2 to clear floor 2		2020	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 160+1800+60=2020
Sleeping occupants on Floor 4 (The last occupant in the building to clear the building)			
Pre-movement Time (s)	t_p	1800	The occupants are asleep and under the care of trained staff (remote from the room of fire origin)
Travel Time (s)	t_t	53	Travel to the nearest exit
Queuing Time (s)	t_q	171	Clear occupants above the first floor
RSET (s) – The last occupant to clear the building		2131	Required safety egress time for the last occupant in the building 160+1800+171=2131

Table 5-16: Required inputs to determine the evacuation time for hostel fire

FIRE LOCATED IN HOSTEL (HOSTEL FIRE)			
Component		**Value**	**Remark**
Detection Time (s)	t_d	59	Smoke detector activation time
HOSTEL (ROOM OF FIRE ORIGIN)			
Pre-movement Time (s)	t_p	60	The occupants are asleep and unfamiliar with the building (remote from the room of fire origin)
Travel Time (s)	t_t	24	Clear hostel to corridor
Travel Time (s)	t_t	50	Clear hostel to a stairway
Queuing Time (s)	t_q	18	Clear hostel to corridor
Queuing Time (s)	t_q	32	Clear hostel to a stairway
RSET (s) – Occupants clear hostel		143	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 59+60+24=143
RSET (s) – hostel occupants to clear floor 3		169	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 59+60+50=169
Sleeping occupants (The last occupant on floor 3 to clear floor 3)			
Pre-movement Time (s)	t_p	1800	The occupants are awake and under the care of trained staff (remote from the room of fire origin)
Travel Time (s)	t_t	47	Travel to a stairway
Queuing Time (s)	t_q	68	Clear occupants to a stairway
RSET (s) – The last occupant on floor 3 to clear floor 3		1927	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 59+1800+68=1927
Sleeping occupants on Floor 4 (The last occupant in the building to clear the building)			
Pre-movement Time (s)	t_p	1800	The occupants are asleep and under the care of trained staff (remote from the room of fire origin)
Travel Time (s)	t_t	53	Travel to the nearest exit
Queuing Time (s)	t_q	171	Clear occupants above the first floor
RSET (s) – The last occupant to clear the building		2030	Required safety egress time for the last occupant in the building 59+1800+171=2030

5.3.5 ASET and RSET Analysis

The results of ASET and RSET were determined in section 5.3.3 and calculated in section 5.3.4 respectively. The performance objective of DFS1 is to "provide a tenable environment for occupants in the event of a fire while they escape to a safe place"[1]. In order to determine occupants can evacuate to a safe place, the values of ASET and RSET were compared. ASET shall be greater than RSET to demonstrate compliance with the DFS1. A summary of ASET and RSET for the cafeteria fire, physiotherapy fire, laboratory fire and hostel fire are provided in Table 5-17.

Table 5-17: ASET and RSET for hospital

FIRE LOCATED IN CAFETERIA (CAFETERIA FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Cafeteria	881	440	441	200	Comply
Corridor-2	> 7200	502[a]	> 6700	> 1430	Comply
Stairway	> 7200	2130[b]	> 5070	> 338	Comply
FIRE LOCATED IN PHYSIOTHERAPY (PHYSIOTHERAPY FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Physiotherapy	1150	264	881	434	Comply
Corridor-2	2960	454[c]	2500	651	Comply
Corridor-2	2960	514[a]	2440	575	Comply
Stairway	> 7200	2120[b]	> 5080	> 340	Comply
FIRE LOCATED IN LABORATORY (LABORATORY FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Laboratory	1080	255	818	412	Comply
Corridor-1	1990	264[d]	1710	713	Comply
Corridor-2	> 7200	2010[e]	> 5190	> 356	Comply
Stairway	> 7200	2140[b]	> 5060	> 338	Comply
FIRE LOCATED IN HOSTEL (HOSTEL FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Hostel	916	143	773	641	Comply
Corridor-1	1846	169[f]	1680	1090	Comply
Corridor-2	> 7200	1930[g]	> 5270	> 373	Comply
Stairway	> 7200	2030[b]	> 5170	> 354	Comply

Note a: Last occupant on floor 1 to clear the building through the corridor-2 to the outside

Note b: Last sleeping occupant on floor 4 to clear the building through the enclosed stairway

Note c: Physiotherapy occupant on floor 1 to clear the building through the corridor-2 to the outside
Note d: Laboratory occupant on floor 2 to clear the floor through the corridor-1 to the enclosed stairway
Note e: Last occupant on floor 2 to clear the floor to the enclosed stairway through the corridor-2
Note f: Hostel occupant on floor 3 to clear the floor through the corridor-1 to the enclosed stairway
Note g: Hostel occupant on floor 3 to clear the floor to the enclosed stairway through the corridor-2

5.3.6 Conclusion of Design Fire Scenario One (Challenging Fire)

The analysis using the fire modelling rules undertaken in BRANZFIRE showed that all occupants in the hospital had sufficient time to make their escape before the untenable condition occurred. The results of DFS1 were summarised in Table 5-18 and it showed that the hospital achieved DFS1.

Table 5-18: Summary of DFS1 in hospital

Output	Cafeteria Fire		Physiotherapy Fire		Laboratory Fire		Hostel Fire	
	Cafeteria	Corridor	Physio	Corridor	Lab	Corridor	Hostel	Corridor
ASET	881	>7199	1145	2957	1075	1986	916	1846
RSET	440	2131	264	2124	255	264	143	169
Margin (s)	441	5068	881	833	820	1722	773	1677
Margin (%)	200	>338	434	139	422	752	641	1092
Scenario Result	Comply	Comply	Comply	Comply	Comply	Comply	Comply	Comply

5.4 Design Fire Scenario Two (Blocked Exit)

This scenario addressed the concern for single means of egress that served more than 50 people. Each area in the building was provided more than one escape route. Design Fire Scenario Two was achieved.

5.5 Design Fire Scenario Three (Fire in Unoccupied Room)

The building was protected by an automatic sprinkler system and the system was installed in accordance with NFPA13 [27]. Design Fire Scenario Three was achieved.

5.6 Design Fire Scenario Four (Concealed Space)

The building was protected by an automatic sprinkler system and the system was installed in accordance with NFPA13 [27]. Design Fire Scenario Four was achieved.

5.7 Design Fire Scenario Five (Smouldering Fire)

This scenario addressed the concern for sleeping occupants. Smoke alarm system was installed in the sleeping area, therefore there was no requirement to test this scenario in this building and Design Fire Scenario Five was achieved.

5.8 Design Fire Scenario Six (Spread to Other Property)

All exterior walls were fire rated in accordance with NFPA5000. The west wall, north wall, east wall and south wall was 20.0 m, 15.0 m 20.0 m and 50.0 m to the relevant boundary. To comply with Design Fire Scenario Six, the building might satisfy the requirements of Part 7 of C/AS1.

The building was 9.6 m height and the north wall was over 20.0 m width. Sprinkler system was installed throughout in the building. The building contained Fire Hazard Category 1 materials as per C/AS1 Table 2.1. According to C/AS1 Table 7.2/6 and Clause 7.3.12 [2], the north wall allowed 100% unprotected area. Design Fire Scenario Six was achieved.

5.9 Design Fire Scenario Seven (Vertical External Fire Spread)

The building contained sleeping occupancies on the upper floor and the building height was less than 10 m. The building was sprinklered protected to prevent external fire spread between floors via the exterior openings and the exterior walls were constructed of non-combustible concrete to reduce the probability of vertical fire spread over the surface of an exterior cladding. Therefore, the building did not require testing in this scenario and Design Fire Scenario Seven was achieved.

5.10 Design Fire Scenario Eight (Interior Surface Finishes)

NFPA5000 regulated interior finish materials based upon flame spread, smoke production, and occupancy of the area. ASTM E-84 [28] was the principal test method used by NFPA5000 to characterise flame spread and smoke production. NFPA286 [29] also allowed for large scale testing of interior finishes.

The objective of this scenario was to maintain tenable conditions on escape routes while occupants were evacuating the area and to prevent rapid fire spread that could compromise the retreat of firefighters. Performance criteria for lining materials depend on their location in the building and the occupancy type. Sprinkler system is installed throughout the building and therefore the smoke production rate criteria are not required to be tested. The interior finish material in the building is gypsum plasterboard and achieves a time to flashover not less than 20 minutes under test conditions of ISO 9705 [30]. The interior finish material in the stairway was non-combustible concrete and achieved a time to flashover not less than 20 minutes under test conditions of ISO 9705 [30]. The building achieved Design Fire Scenario Eight.

5.11 Design Fire Scenario Nine (Fire Service Operations)

The objective of this scenario was to facilitate firefighters operation and avoid unexpected collapse that would endanger fire service personnel within or near to the building. The area of the building was greater than 1500 m^2 and contained Fire Hazard Category 1 materials. Water from street hydrants was available via a pumping appliance parked closed to the building. Any point within the building was reached within 75 m either from the street floor or from a safe path and the building was protected by sprinkler system, therefore it was not necessary to demonstrate firefighter tenability for heat and smoke exposure.

Structural stability criteria for firefighters were achieved as all floors are provided 2 hours fire resistance rating and firefighters were able to access to all levels from a 2 hours fire rated stairway. The automatic sprinkler system, and fire rated floors and stairways would enhance safe access for search and rescue operations. The building was achieved Design Fire Scenario Nine.

5.12 Design Fire Scenario Ten (Robustness Check)

This scenario applied to areas with more than 150 people or more than 6 people in sleeping care occupancy. The robustness of the design was tested by considering the design fire with each key fire safety system rendered ineffective in turn excluding fire sprinkler system and smoke detection system installed to a recognised standard. A deterministic ASET/RSET approach was used to assess the safety of a design with a fire/smoke door ineffective. All occupants in the hospital had sufficient time to make their escape before the untenable condition occurred. The building achieved Design Fire Scenario Ten. A summary of ASET and RSET is provided in Table 5-19.

Table 5-19: ASET and RSET for hospital with a fire/smoke door ineffective

FIRE LOCATED IN CAFETERIA (CAFETERIA FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Cafeteria	1090	440	650	247	Comply
Corridor-2	2670	502[a]	2168	531	Comply
Stairway	>7200	2130[b]	>5070	>338	Comply
FIRE LOCATED IN PHYSIOTHERAPY (PHYSIOTHERAPY FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Physiotherapy	1140	264	776	313	Comply
Corridor-2	2170	454[c]	1710	447	Comply
Corridor-2	2170	514[a]	1650	421	Comply
Stairway	2770	2120[b]	646	130	Comply
FIRE LOCATED IN LABORATORY (LABORATORY FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Laboratory	1110	255	855	435	Comply
Corridor-1	1710	264[d]	1446	647	Comply
Corridor-2	>7200	2010[e]	>5190	358	Comply
Stairway	>7200	2140[b]	>5060	336	Comply
FIRE LOCATED IN HOSTEL (HOSTEL FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Hostel	991	206	785	481	Comply
Corridor-1	1690	232[f]	1460	728	Comply
Corridor-2	>7200	1990[g]	>5210	361	Comply
Stairway	>7200	2090[b]	>5110	344	Comply

Note a: Last occupant on floor 1 to clear the building through the corridor-2 to the outside

Note b: Last sleeping occupant on floor 4 to clear the building through the enclosed stairway

Note c: Physiotherapy occupant on floor 1 to clear the building through the corridor-2 to the outside

Note d: Laboratory occupant on floor 2 to clear the floor through the corridor-1 to the enclosed stairway

Note e: Last occupant on floor 2 to clear the floor to the enclosed stairway through the corridor-2

Note f: Hostel occupant on floor 3 to clear the floor through the corridor-1 to the enclosed stairway

Note g: Hostel occupant on floor 3 to clear the floor to the enclosed stairway through the corridor-2

5.13 Summary for Case Study Building Two (Hospital)

Ten design fire scenarios were applied to the building. The building did not meet the performance measure of the framework because it failed to achieve the DFS10. A summary of Design Fire Scenario One to Design Fire Scenario Ten in the hospital were provided in Table 5-20.

Table 5-20: Summary of design fire scenarios in the hospital

Design Fire Scenario	Result for the hospital
DSF1: Challenging Fire	Comply
DSF2: Block Exit	Comply
DSF3: Fire in Unoccupied Spaces	Comply
DSF4: Fire in Concealed Spaces	Comply
DSF5: Smouldering Fire	Comply
DSF6: Spread to Other Property	Comply
DSF7: Vertical External Fire Spread	Comply
DSF8: Interior Surface Finishes	Comply
DSF9: Fire Service Operations	Comply
DSF10: Robustness Check	Comply

6 Case Study Building Three (Shopping Mall)

6.1 Building Description

The building is a four storeys shopping mall which contains a number of small, medium retail shops and major retail tenancies for visitors to walk from shops to shops as well as a large communicating space. Parking structures are located on every floor whilst retail spaces are on floors 2 and 3 only. Floor 1 contains parking structure, storage areas and truck access. Floor 2 and 3 contain retail spaces, food courts and restaurants and are connected by the central atrium. Floor 4 contains parking structure and provides access to lower floors through escalators, stairways and lifts.

The building is 130 m wide, 211 m long and 14.4 m height. Floor 2 and floor 3 has floor to floor height of 4.5 m and 2.4 m on floor 1. The atrium is 3.0 m extended above floor 4. Fuel dispensing devices are not contained in the building. The west wall is 25 m to the relevant boundary, the north wall is 30 m to the relevant boundary, the east wall is 20 m to the relevant boundary and the south wall is 15 m to the relevant boundary. The activities within the building are summarised in Table 6-1 and the building layouts are provided in Figure 6-1, Figure 6-2, Figure 6-3 and Figure 6-4.

Table 6-1: Description of Building

Floor	Activities	Detail
1	Parking structure and storage areas	Ground floor
2	Retail tenancies, restaurant, food court and car park	Main entrance with access from street level
3	Retail tenancies, restaurant, food court and car park	Atrium connected to floor 2
4	Roof parking structure	Roof level

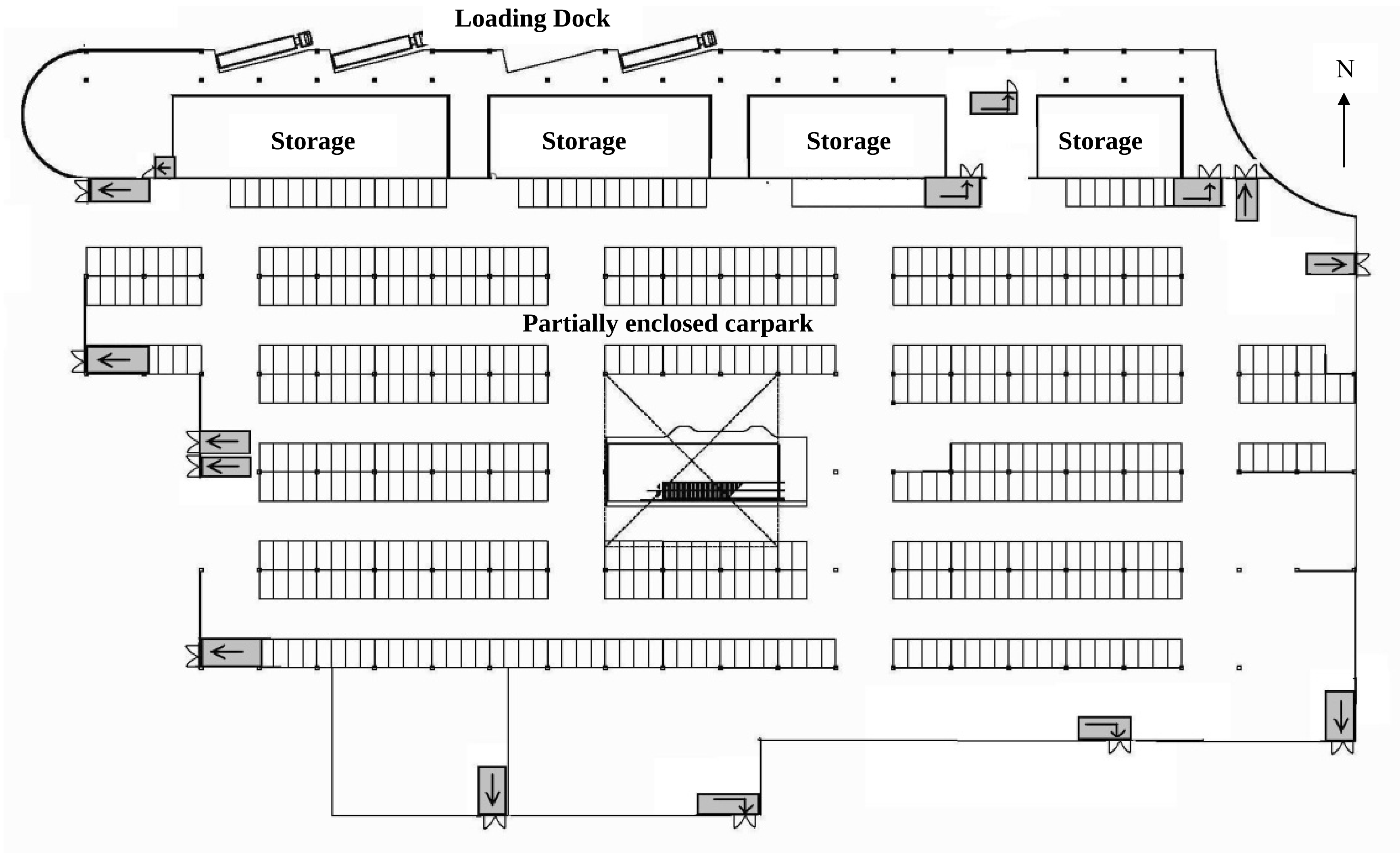

Figure 6-1: Plan view of floor 1 in shopping mall (not to scale)

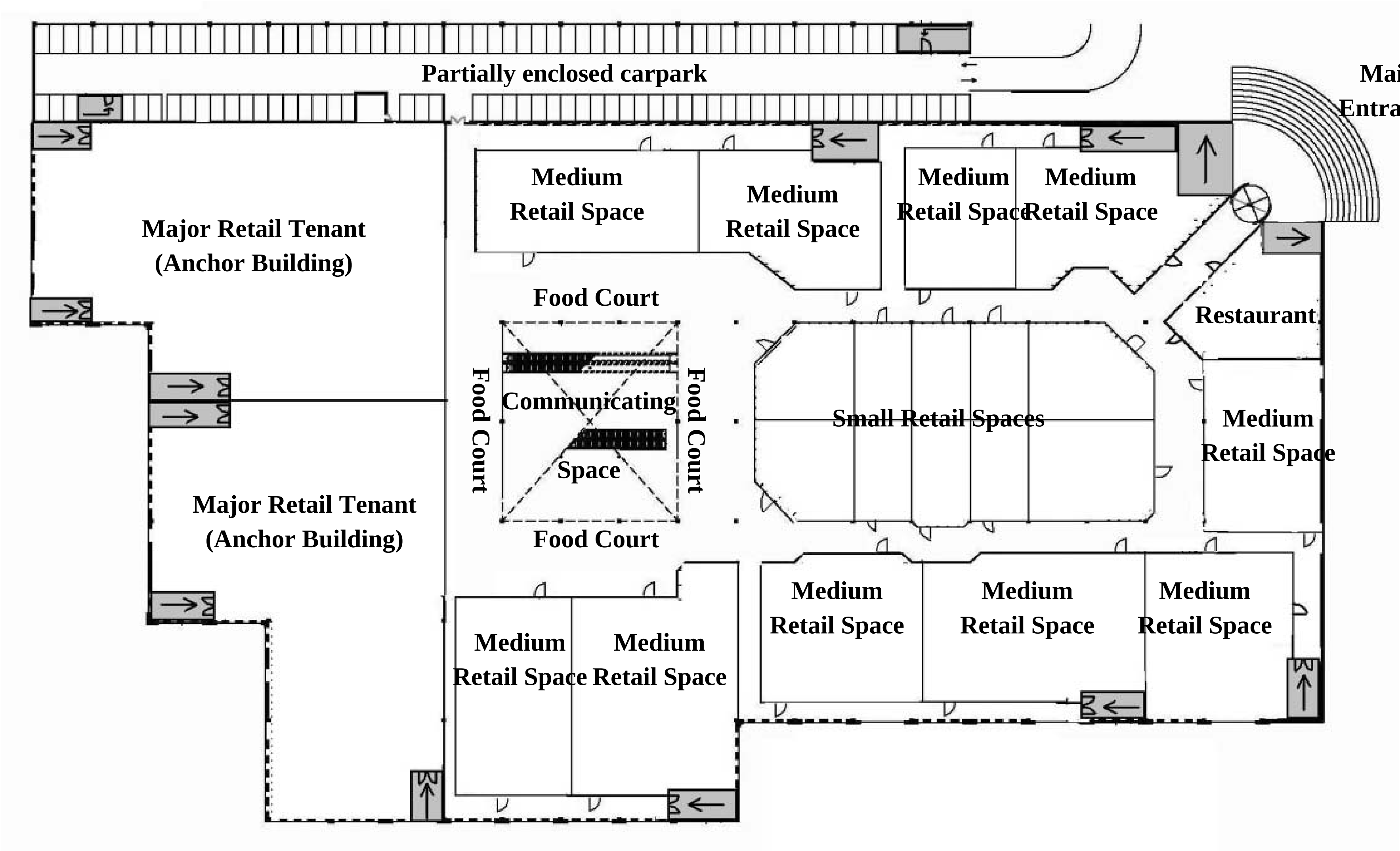

Figure 6-2: Plan view of floor 2 in shopping mall (not to scale)

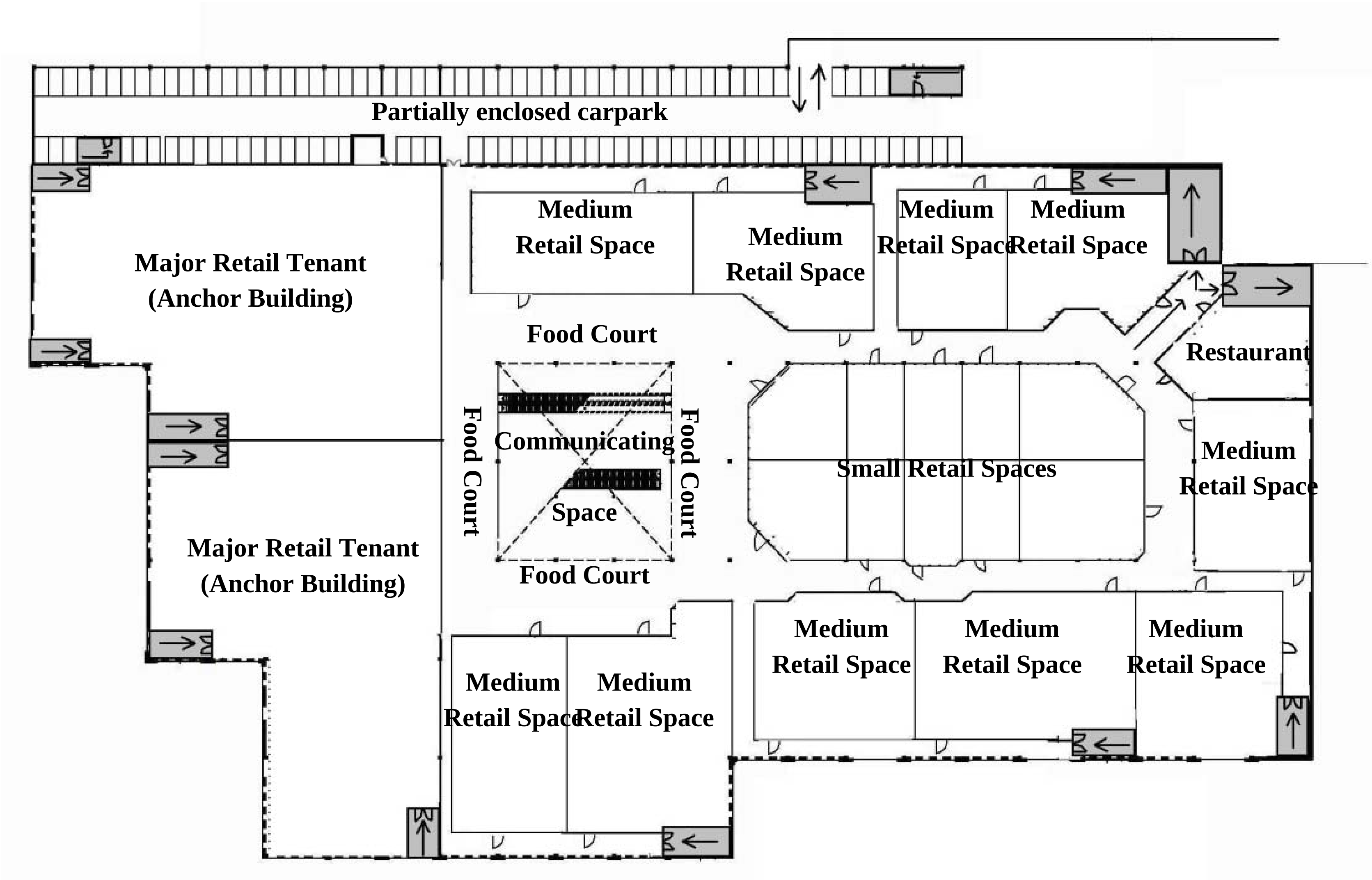

Figure 6-3: Plan view of floor 3 in shopping mall (not to scale)

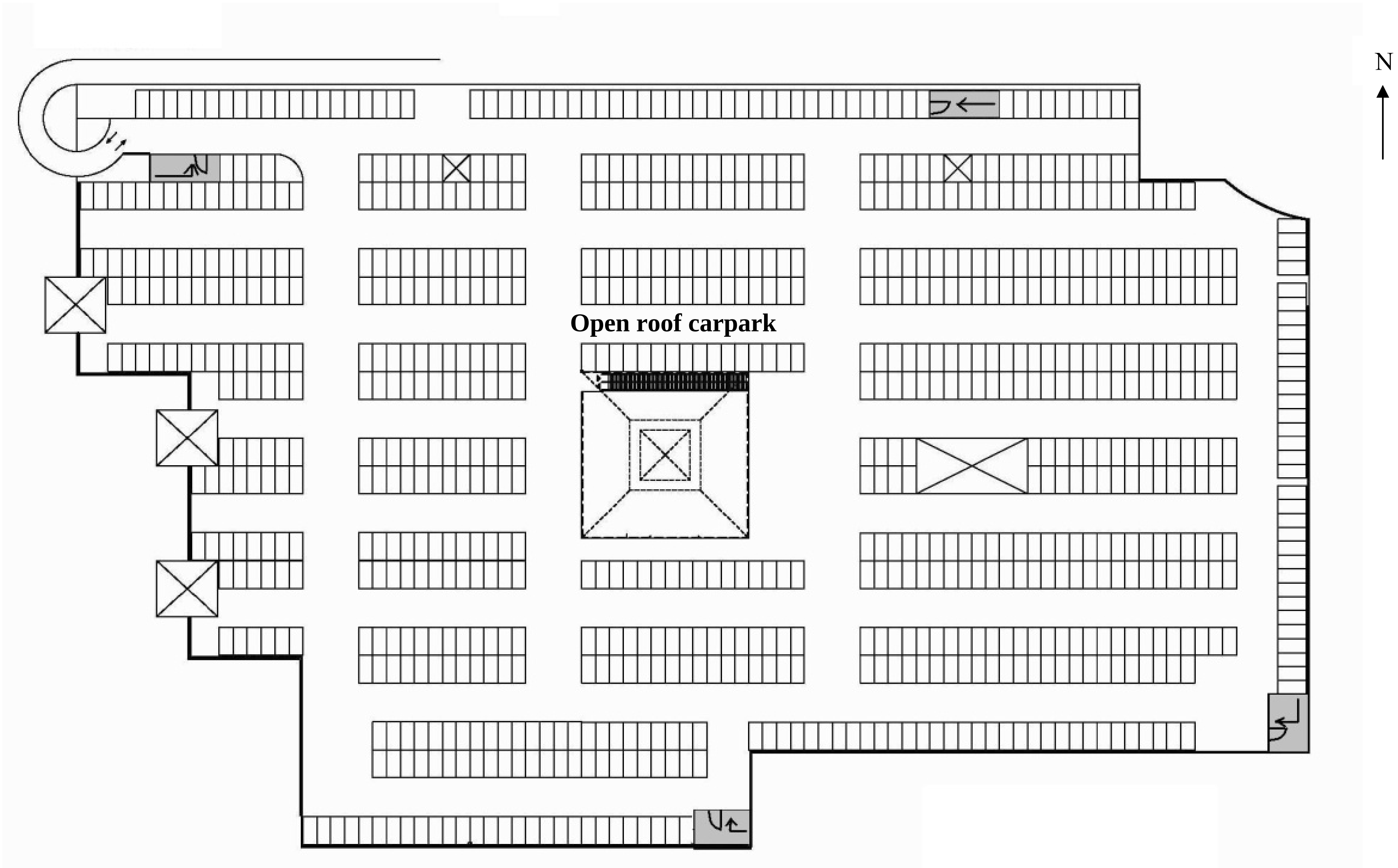

Figure 6-4: Plan view of floor 4 in shopping mall (not to scale)

6.2 NFPA5000 Audit

The building will satisfy the prescriptive requirement of the NFPA5000 if the following fire requirements are implemented. A detailed NFPA5000 audit report including building layouts, relevant boundaries, occupancy types, occupant loads, required fire protection systems and exits and egress routes can be found in Appendix A3.

1. The building, except parking structure on roof level, is protected by an approved, supervised automatic sprinkler system in accordance with NFPA13
2. Retail spaces with area less than 280 m^2 are permitted to have single means of egress. Other areas in the building are provided at least two means of egress and at least two accessible means of egress
3. Inside open stairway is permitted to use as a means of egress at floor 3 and is not required to provide fire resistance rating or smoke barriers for walls and door assemblies
4. Anchor buildings are fire separated from the other places and are provided independent means of egress
5. Wall with fire resistance rating is required between retail spaces and no fire resistance rating is required between a retail space and the shopping mall.
6. All interior enclosed stairways are constructed as a smoke and fire barrier
7. Parking structures are fire separated from the retail spaces except that the door openings in the fire barrier is not required any fire resistance rating but require to be equipped with self-closing device to restrict the passage of smoke
8. Smoke control system is not required in the atrium but sprinklers are installed between retail spaces and the shopping mall at a certain interval and distance. Doors in the walls are installed with self-closing devices.
9. The minimum 1.12 m clear stair width for discharge from a stairway has been achieved. The tread depth and the riser height of the stairs are 0.3 m and 0.15 m respectively

6.3 Design Fire Scenario One (Challenging Fire)

The framework defines a set of design fire scenarios to evaluate the case study building. The first design fire scenario is DFS1 which provides a credible worst case scenario to challenge the fire protection features of the building. In this scenario, occupancy-specific design fires are located in several places within the building with all fire safety systems working as intended.

6.3.1 Description of Fire Modelling in BRANZFIRE

6.3.1.1 Anchor Building Fire

The anchor building on floor 3, the stairway within the anchor building and the communicating space on floor 3 were modelled in BRANZFIRE (Figure 6-5). The room dimensions are shown in Table 6-2. Windows and a number vents are connected between rooms or between room and the outside of the building in accordance with the fire modelling rules in section 2.6. Table 6-3 provides the detail of the vents used in BRANZFIRE between compartments and to the outside. Construction materials for walls, floors and ceilings in each of the five rooms modelled in BRANZFIRE are shown in

Table 6-4.

Table 6-2: Summary of room dimensions included in BRANZFIRE modelling for anchor building fire

Room	Width (m)	Length (m)	Height (m)	Floor Height (m)	Zone/Layer
(1) Communicating space	56.0	60.8	7.5	6.9	Two Zone/Layer
(2) Anchor Building - 3	59.7	43.6	4.5	6.9	Two Zone/Layer
(3) Stairway	9.6	5.0	13.8	0.0	Single Zone/Layer

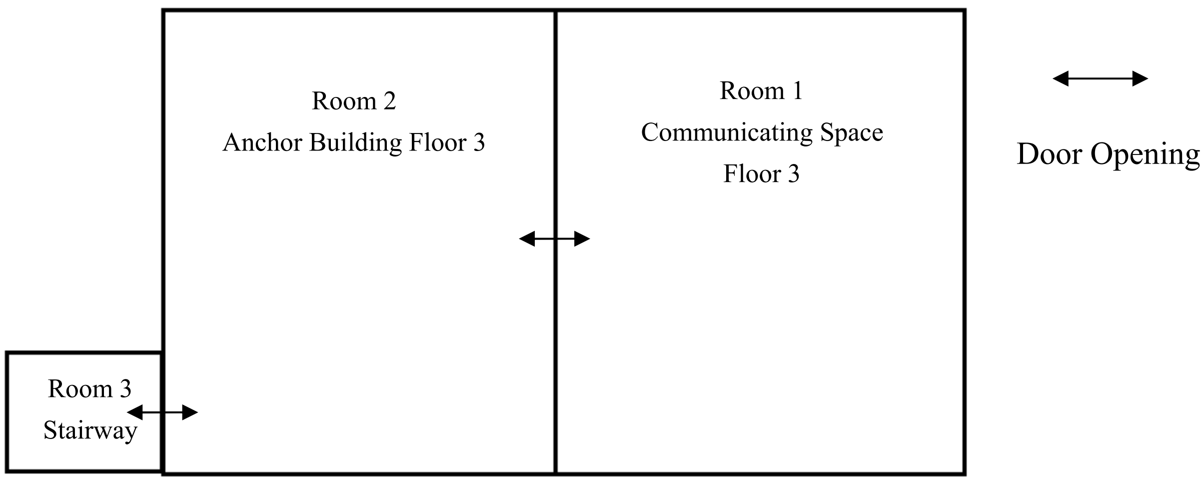

Figure 6-5: BRANZFIRE modelling for anchor building fire

Table 6-3: Summary of vent dimensions connecting rooms included in BRANZFIRE modelling for anchor building fire

Room	Vent width (m)	Vent height (m)	Sill Height (m)	Opening Time (s)	Closing Time (s)	Function
Communicating Space to Anchor building – 3	20.0	2.03	0	Always	None	Door
Anchor building – 3 to Stairway	0.4	2.03	0	Detection	+ 234	Door

Table 6-4: Summary of surface, material and substrate for various rooms in BRANZFIRE modelling

Room	Wall Material	Ceiling Material	Floor Material
	Surface	Surface	Surface
All rooms	Concrete	Concrete	Concrete

6.3.1.2 Restaurant Fire

The restaurant on floor 3, the communicating space on floor 3 and the stairway within the communicating space were modelled in BRANZFIRE (Figure 6-6). The room dimensions are shown in Table 6-5. Windows and a number vents were connected between rooms or between room and the outside of the building in accordance with the fire modelling rules in section 2.6. Table 6-6 provides the detail of the vents used in BRANZFIRE between compartments and to the outside. Construction materials for walls, floors and ceilings in each of the five rooms modelled in BRANZFIRE are shown in

Table 6-4.

Table 6-5: Summary of room dimensions included in BRANZFIRE modelling for restaurant fire

Room	Width (m)	Length (m)	Height (m)	Floor Height (m)	Zone/Layer
(1) Communicating space	56.0	60.8	7.5	6.9	Two Zone/Layer
(2) Restaurant	16.0	20.0	4.5	6.9	Two Zone/Layer
(3) Stairway	12.6	8.2	13.8	0.0	Single Zone/Layer

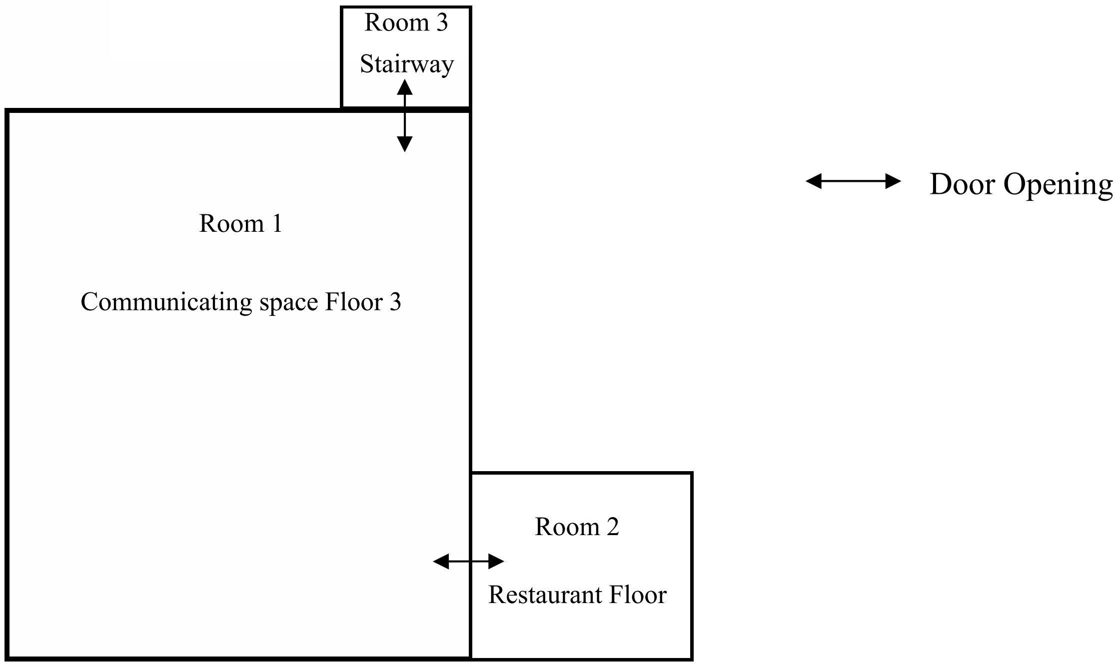

Figure 6-6: BRANZFIRE modelling for restaurant fire

Table 6-6: Summary of vent dimensions connecting rooms included in BRANZFIRE modelling for restaurant fire

Room	Vent width (m)	Vent height (m)	Sill Height (m)	Opening Time (s)	Closing Time (s)	Function
Communicating Space to Restaurant	0.81	2.03	0	Always	None	Door
Communicating Space to Restaurant	10.0	2.03	0	1372	None	Windows
Communicating Space to Stairway	1.1	2.03	0	Detection	+ 308	Door

6.3.1.3 Small Shop Fire

The small shop on floor 3, the communicating space on floor 3 and the stairway within the communicating space were modelled in BRANZFIRE (Figure 6-7). The room dimensions are shown in Table 6-7. Windows and a number vents are connected between rooms or between room and the outside of the building in accordance with the fire modelling rules in section 2.6. Table 6-8 provides the detail of the vents used in BRANZFIRE between compartments and to the outside. Construction materials for walls, floors and ceilings in each of the five rooms modelled in BRANZFIRE are shown in Table 6-4..

Table 6-7: Summary of room dimensions included in BRANZFIRE modelling for small shop fire

Room	Width (m)	Length (m)	Height (m)	Floor Height (m)	Zone/Layer
(1) Communicating space	56.0	60.8	7.5	6.9	Two Zone/Layer
(2) Small shop	15.0	16.0	4.5	6.9	Two Zone/Layer
(3) Stairway	12.6	8.2	13.8	0.0	Single Zone/Layer

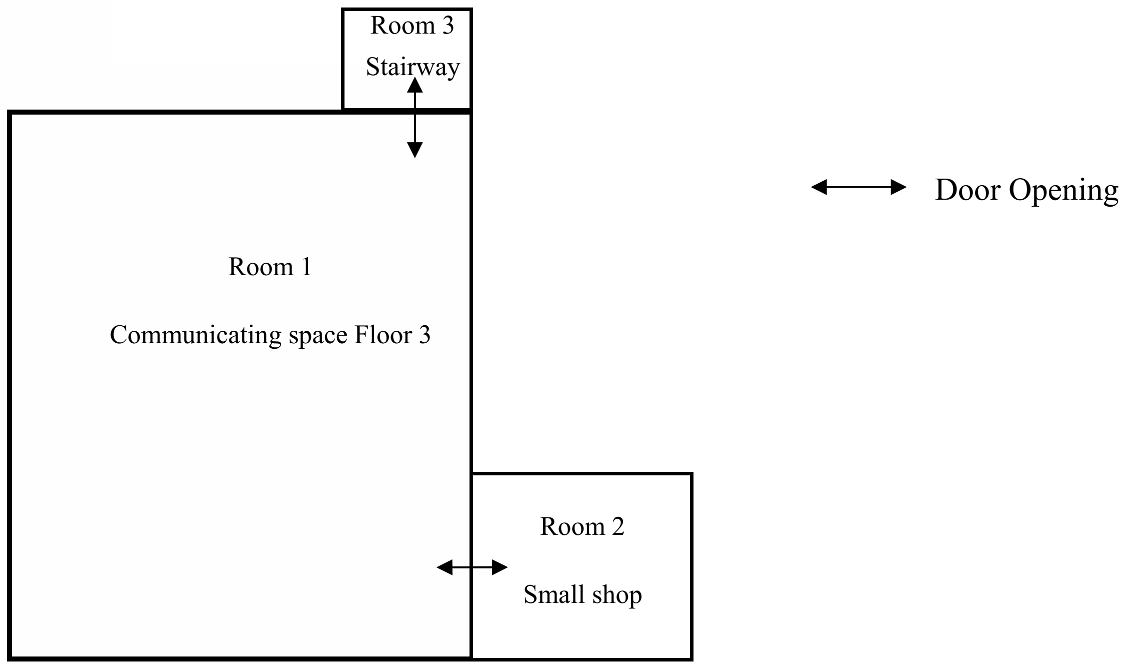

Figure 6-7: BRANZFIRE modelling for small shop fire

Table 6-8: Summary of vent dimensions connecting rooms included in BRANZFIRE modelling for small shop fire

Room	Vent width (m)	Vent height (m)	Sill Height (m)	Opening Time (s)	Closing Time (s)	Function
Communicating Space to Small shop	0.4	2.03	0	Always	None	Door
Communicating Space to Small shop	10.0	2.03	0	983	None	Windows
Communicating Space to Stairway	1.1	2.03	0	Detection	+ 308	Door

6.3.1.4 Communicating Space Fire

The communicating space on floor 2 and 3, the stairway within the communicating space and the anchor building on floor 3 were modelled in BRANZFIRE (Figure 6-8). The room dimensions are shown in Table 6-9. Windows and a number vents were connected between rooms or between room and the outside of the building in accordance with the fire modelling rules in section 2.6. Table 6-10 provides the detail of the vents used in BRANZFIRE between compartments and to the outside. Construction materials for walls, floors and ceilings in each of the five rooms modelled in BRANZFIRE are shown in Table 6-4.

Table 6-9: Summary of room dimensions included in BRANZFIRE modelling for communicating space fire

Room	Width (m)	Length (m)	Height (m)	Floor Height (m)	Zone/Layer
(1) Communicating space	56.0	60.8	12	2.4	Two Zone/Layer
(2) Anchor Building - 3	59.7	43.6	4.5	6.9	Two Zone/Layer
(3) Stairway	12.6	8.2	13.8	0.0	Single Zone/Layer

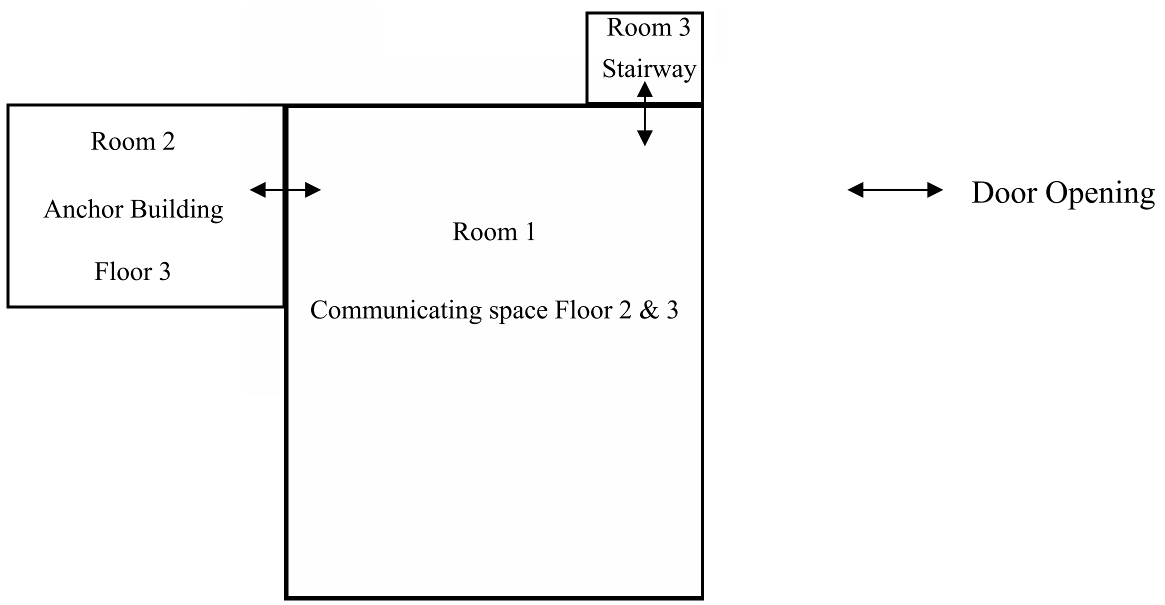

Figure 6-8: BRANZFIRE modelling for communicating space fire

Table 6-10: Summary of vent dimensions connecting rooms included in BRANZFIRE modelling for communicating space fire

Room	Vent width (m)	Vent height (m)	Sill Height (m)	Opening Time (s)	Closing Time (s)	Function
Communicating Space to Anchor building – 3	20.0	2.03	4.5	Always	None	Door
Communicating Space to Stairway	1.1	2.03	0	Detection	+ 308	Door

6.3.2 Design Fire

The area of anchor building, restaurant, small shop and communicating space are greater than 200 m^2 and are required to be analysed under DFS1. The design fire growth rates in different areas and the peak heat release rate from BRANZFIRE modelling are detailed in Table 6-11. The design fire in all areas are assumed to grow as fast t^2.

Windows in the anchor building – 3 and communicating space were not broken as the upper temperature did not exceed 500 ^oC, or the heat release rate was not reduced after the fire reached peak heat release rate. Heat release rate was reduced after 1372 s and after 983 s in restaurant fire and the small shop fire due to ventilation control. Therefore, it was decided to manually break all the windows in the restaurant and the small shop at 1372 s and 983 s respectively as required by the modelling rules specified in the framework.

Table 6-11 Design fire used in BRANZFIRE modelling for shopping mall

Fire Location	Fire Growth Rate (kW)	Time to reach 500^{o}C or when the Heat Release Rate reduces (s)	Peak Heat Release Rate (MW) from BRANZFIRE Modelling
Anchor building – 3	$0.047t^2$	Not reach	2.8
Restaurant	$0.047t^2$	1372	1.9
Small shop	$0.047t^2$	983	1.8
Communicating space	$0.047t^2$	Not reach	10.0

Soot and carbon monoxide production rate used in the BRANZFIRE modelling are listed below:

- Pre-flashover species yield for soot (Y_{soot}) is 0.07 kg/kg
- Pre-flashover species yield for carbon monoxide (Y_{co}) is 0.04 kg/kg
- Post-flashover species yield for soot (Y_{soot}) is 0.14 kg/kg
- Post-flashover species yield for carbon monoxide (Y_{soot}) is 0.40 kg/kg

6.3.3 BRANZFIRE Modelling Results to determine ASET

The fire modelling rules of the framework require some way to alert the occupants. An automatic sprinkler system was required from NFPA5000 and was installed throughout the building in order to control and suppress the fire as well as to alert the occupants. A standard response sprinkler system was installed throughout the building and therefore the criterion for occupant tenability was based on FED for carbon monoxide. The BRANZFIRE results for fire located in the anchor building, restaurant, small shop and communicating space are summarized in Table 6-12.

Table 6-12 BRANZFIRE results DFS1 for shopping mall

FIRE LOCATED IN ANCHOR BUILDING – 3 ON FLOOR 3 (ANCHOR BUILDING FIRE)			
Room	**Visibility (10m)**	**FED (Thermal)**	**FED(CO)**
Communicating space on floor 3	2560s	> 3600s	> 3600s
Anchor building – 3 on floor 3	744s	1350s	2320s
Stairway	2490s	> 3600s	> 3600s
FIRE LOCATED IN RESTAURANT ON FLOOR 3 (RESTAURANT FIRE)			
Room	**Visibility (10m)**	**FED (Thermal)**	**FED(CO)**
Communicating space on floor 3	2270s	> 3580s	3100s
Restaurant on floor 3	192s	320s	608s
Stairway	> 3580s	> 3580s	> 3580s
FIRE LOCATED IN SMALL SHOP ON FLOOR 3 (SMALL SHOP FIRE)			
Room	**Visibility (10m)**	**FED (Thermal)**	**FED(CO)**
Communicating space on floor 3	19440s	> 3600s	3185s
Small shop on floor 3	160s	262s	512s
Stairway	> 3600s	> 3600s	> 3600s
FIRE LOCATED IN COMMUNICATING SPACE ON FLOOR 2 (COMMUNICATING SPACE FIRE)			
Room	**Visibility (10m)**	**FED (Thermal)**	**FED(CO)**
Communicating space on floor 3	431s	838s	2250s
Anchor building – 3 on floor 3	433s	> 3600s	3390s
Stairway	1830s	> 3600s	> 3600s

6.3.4 RSET Calculations

All occupants in the shopping mall are assumed to be awake as the primary use of the building is not for sleeping purpose. The building is open to public and the occupants are assumed to be unfamiliar with the escape routes whilst the employees are considered familiar with escape routes. The calculations of RSET were explained in section 2.5. RSET is a sum of detection time, pre-movement time, and travel time or queuing time. A summary of evacuation time for the hospital is provided in Table 6-13 to Table 6-16 and Appendix B.

Table 6-13: Required inputs to determine the evacuation time for anchor building fire

FIRE LOCATED IN ANCHOR BUILDING – 3 ON FLOOR 3 (ANCHOR BUILDING FIRE)			
Component		**Value**	**Remark**
Detection Time (s)	t_d	244	Sprinkler activation time
ANCHOR BUILDING – 3 ON FLOOR 3 (ROOM OF FIRE ORIGIN)			
Pre-movement Time (s)	t_p	60	The occupants are awake and unfamiliar with the building (Room of fire origin)
Travel Time (s)	t_t	59	Travel to stairway
Queuing Time (s)	t_q	234	Clear occupants to stairway
RSET (s) – Clear Anchor building - 3		538	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 244+60+234=538
Tenants on floor 3 (The last occupant on floor 3 to clear floor 3)			
Pre-movement Time (s)	t_p	120	The occupants are awake and unfamiliar with the building (remote from the room of fire origin)
Travel Time (s)	t_t	106	Travel to stairway
Queuing Time (s)	t_q	308	Clear occupants to stairway
RSET (s) – The last occupant on floor 3 to clear floor 3		672	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 244+120+308=672
Car park on floor 4 (The last occupant in the building to clear the building)			
Pre-movement Time (s)	t_p	120	The occupants are awake and unfamiliar with the building (remote from the room of fire origin)
Travel Time (s)	t_t	95	Travel to stairway
Queuing Time (s)	t_q	176	Clear occupants to stairway

RSET (s) – The last occupant to clear the building		540	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 244+120+176=540

Table 6-14: Required inputs to determine the evacuation time for restaurant fire

FIRE LOCATED IN RESTAURANT ON FLOOR 3 (RESTAURANT FIRE)			
Component		**Value**	**Remark**
Detection Time (s)	t_d	200	Sprinkler activation time
RESTAURANT ON FLOOR 3 (ROOM OF FIRE ORIGIN)			
Pre-movement Time (s)	t_p	60	The occupants are awake and unfamiliar with the building (Room of fire origin)
Travel Time (s)	t_t	26	Travel to mall area
Queuing Time (s)	t_q	264	Clear occupants to mall area
RSET (s) – Clear restaurant		524	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 200+60+264=524
Tenants on floor 3 (The last occupant on floor 3 to clear floor 3)			
Pre-movement Time (s)	t_p	120	The occupants are awake and unfamiliar with the building (remote from the room of fire origin)
Travel Time (s)	t_t	106	Travel to stairway
Queuing Time (s)	t_q	308	Clear occupants to stairway
RSET (s) – The last occupant on floor 3 to clear floor 3		628	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 200+120+308=628
Car park on floor 4 (The last occupant in the building to clear the building)			
Pre-movement Time (s)	t_p	120	The occupants are awake and unfamiliar with the building (remote from the room of fire origin)
Travel Time (s)	t_t	95	Travel to stairway
Queuing Time (s)	t_q	176	Clear occupants to stairway
RSET (s) – The last occupant to clear the building		496	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 200+120+176=496

Table 6-15: Required inputs to determine the evacuation time for small shop fire

FIRE LOCATED IN SMALL SHOP ON FLOOR 3 (SMALL SHOP FIRE)			
Component		**Value**	**Remark**
Detection Time (s)	t_d	194	Sprinkler activation time
SMALL SHOP ON FLOOR 3 (ROOM OF FIRE ORIGIN)			
Pre-movement Time (s)	t_p	60	The occupants are awake and unfamiliar with the building (Room of fire origin)
Travel Time (s)	t_t	19	Travel to mall area
Queuing Time (s)	t_q	132	Clear occupants to mall area
RSET (s) – Clear small shop		386	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 194+60+132=386
Tenants on floor 3 (The last occupant on floor 3 to clear floor 3)			
Pre-movement Time (s)	t_p	120	The occupants are awake and unfamiliar with the building (remote from the room of fire origin)
Travel Time (s)	t_t	106	Travel to stairway
Queuing Time (s)	t_q	308	Clear occupants to stairway
RSET (s) – The last occupant on floor 3 to clear floor 3		622	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 194+120+308=622
Car park on floor 4 (The last occupant in the building to clear the building)			
Pre-movement Time (s)	t_p	120	The occupants are awake and unfamiliar with the building (remote from the room of fire origin)
Travel Time (s)	t_t	95	Travel to stairway
Queuing Time (s)	t_q	176	Clear occupants to stairway
RSET (s) – The last occupant to clear the building		490	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 194+120+176=490

Table 6-16: Required inputs to determine the evacuation time for communicating space fire

FIRE LOCATED IN COMMUNICATING SPACE ON FLOOR 2 (COMMUNICATING SPACE FIRE)			
Component		**Value**	**Remark**
Detection Time (s)	t_d	467	Sprinkler activation time
Anchor building - 3 on floor 3			
Pre-movement Time (s)	t_p	120	The occupants are awake and unfamiliar with the building (remote from the room of fire origin)
Travel Time (s)	t_t	59	Travel to stairway
Queuing Time (s)	t_q	234	Clear occupants to stairway
RSET (s) – Clear anchor building - 3		821	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 467+120+234=821
Tenants on floor 3 (The last occupant on floor 3 to clear floor 3)			
Pre-movement Time (s)	t_p	120	The occupants are awake and unfamiliar with the building (remote from the room of fire origin)
Travel Time (s)	t_t	106	Travel to stairway
Queuing Time (s)	t_q	308	Clear occupants to stairway
RSET (s) – The last occupant on floor 3 to clear floor 3		895	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 467+120+308=895
Car park on floor 4 (The last occupant in the building to clear the building)			
Pre-movement Time (s)	t_p	120	The occupants are awake and unfamiliar with the building (remote from the room of fire origin)
Travel Time (s)	t_t	95	Travel to stairway
Queuing Time (s)	t_q	176	Clear occupants to stairway
RSET (s) – The last occupant to clear the building		763	Travel time is not included in the RSET because the queuing time is dominant (Occupants are queuing rather than travelling) 467+120+176=763

6.3.5 ASET and RSET Analysis

The results of ASET and RSET were determined in section 6.3.3 and calculated in section 6.3.4 respectively. The performance objective of DFS1 is to "provide a tenable environment for occupants in the event of a fire while they escape to a safe place"[1]. In order to determine occupants can evacuate to a safe place, the values of ASET and RSET were compared. ASET shall be greater than RSET to demonstrate compliant with the DFS1. A summary of ASET and RSET for the anchor building fire, restaurant fire, small shop fire and communicating space fire are provided in Table 6-17.

Table 6-17: ASET and RSET for shopping mall

FIRE LOCATED IN ANCHOR BUILDING – 3 ON FLOOR 3 (ANCHOR BUILDING FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Anchor Building – 3 Floor 3	2320	538	1790	431	Comply
Communicating Space Floor 3	>3600	672[a]	> 2930	> 536	Comply
Stairway	>3600	540[b]	> 3060	> 666	Comply
FIRE LOCATED IN RESTAURANT ON FLOOR 3 (RESTAURANT FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Restaurant floor 3	608	524	84	116	Comply
Communicating Space Floor 3	3100	628[a]	2470	494	Comply
Stairway	>3600	496[b]	> 3100	> 725	Comply
FIRE LOCATED IN SMALL SHOP ON FLOOR 3 (SMALL SHOP FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Small Shop Floor 3	512	386	126	133	Comply
Communicating Space Floor 3	3180	622[a]	2560	512	Comply
Stairway	> 3600	490[b]	> 3110	> 734	Comply
FIRE LOCATED IN COMMUNICATING SPACE ON FLOOR 2 (COMMUNICATING SPACE FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Anchor Building Floor 3	3390	821	2570	413	Comply
Communicating Space Floor 3	2250	895[a]	1360	251	Comply
Stairway	> 3600	763[b]	> 2840	> 471	Comply

Note a: Last occupant on floor 3 to clear the floor through the communicating space to the nearest fire rated stairway

Note b: Last occupant on floor 4 to clear the building through the enclosed stairway

6.3.6 Conclusion of Design Fire Scenario One

The analysis using the fire modelling rules undertaken in BRANZFIRE showed that all occupants in the shopping mall had sufficient time to make their escape before the untenable condition occurred. The results of DFS1 were summarised in Table 6-18 and it showed that the shopping mall achieved DFS1.

Table 6-18: Summary of DFS1 in shopping mall

Output	Anchor Building Fire		Restaurant Fire		Small Shop Fire		Communicating Space Fire	
	Anchor	Stairway	Rest.	Stairway	Shop	Stairway	Communicating	Stairway
ASET	2320	> 3600	608	> 3580	512	> 3600	2250	> 3600
RSET	538	540	524	496	386	490	895	763
Margin (s)	1710	> 3060	84	> 3100	126	> 3110	1350	> 2840
Margin (%)	431	> 666	116	> 725	133	> 734	251	> 471
Scenario Result	Comply	Comply	Comply	Comply	Comply	Comply	Comply	Comply

6.4 Design Fire Scenario Two (Blocked Exit)

This scenario addressed the concern for single means of egress that serves more than 50 people. Each area in the building was provided more than one escape route. Design Fire Scenario Two was achieved.

6.5 Design Fire Scenario Three (Fire in Unoccupied Room)

The building was protected by an automatic sprinkler system and the system was installed in accordance with NFPA13 [27]. Design Fire Scenario Three was achieved.

6.6 Design Fire Scenario Four (Concealed Space)

The building was protected by an automatic sprinkler system and the system was installed in accordance with NFPA13 [27]. Design Fire Scenario Four was achieved.

6.7 Design Fire Scenario Five (Smouldering Fire)

This scenario addressed the concern for sleeping occupants. The building was not design for sleeping purpose, therefore there was no requirement to test this scenario in this building and Design Fire Scenario Five was achieved.

6.8 Design Fire Scenario Six (Spread to Other Property)

All exterior walls were fire rated in accordance with NFPA5000. The west wall, north wall, east wall and south wall was 25.0 m, 30.0 m 20.0 m and 15.0 m to the relevant boundary. To comply with Design Fire Scenario Six, the building must satisfy the requirements of Part 7 of C/AS1.

The building was 14.4 m height and the south wall is over 20.0 m width. Sprinkler system was installed throughout in the building. The building contained Fire Hazard Category 2 materials as per C/AS1 Table 2.1. According to C/AS1 Table 7.2/6 and Clause 7.3.12 [2], the north wall allows 100% unprotected area. Design Fire Scenario Six was achieved.

6.9 Design Fire Scenario Seven (Vertical External Fire Spread)

The building did not contain sleeping occupancies and the building height is greater than 10 m. The building was sprinkler protected to prevent external fire spread between floors via the exterior openings and the exterior walls were constructed of non-combustible concrete to reduce the probability of vertical fire spread over the surface of an exterior cladding. Therefore, the building did not require testing in this scenario and Design Fire Scenario Seven is achieved.

6.10 Design Fire Scenario Eight (Interior Surface Finishes)

NFPA5000 regulates interior finish materials based upon flame spread, smoke production, and occupancy of the area. ASTM E-84 [28] was the principal test method used by NFPA5000 to characterise flame spread and smoke production. NFPA286 [29] also allowed for large scale testing of interior finishes.

The objective of this scenario was to maintain tenable conditions on escape routes while the occupants were evacuating the area and to prevent rapid fire spread that could compromise the retreat of firefighters. Performance criteria for lining materials depend on their location in the building and the occupancy type. Sprinkler system was installed throughout the building and therefore the smoke production rate criteria were not required to be tested. The interior finish material in the building was gypsum plasterboard and achieves a time to flashover not less than 20 minutes under test conditions of ISO 9705 [30]. The interior finish material in the stairway was non-combustible concrete and achieved a time to flashover not less than 20 minutes under test conditions of ISO 9705 [30]. The building achieved Design Fire Scenario Eight.

6.11 Design Fire Scenario Nine (Fire Service Operations)

The objective of this scenario was to facilitate firefighters operation and avoid unexpected collapse that would endanger fire service personnel within or near to the building. The area of the building was greater than 1500 m^2 and contained Fire Hazard Category 2 materials. Water from street hydrants was available via a pumping appliance parked closed to the building. Any point within the building was reached within 75 m either from the street floor or from a safe path and the building was protected by sprinkler system, therefore it was not necessary to demonstrate firefighter tenability for heat and smoke exposure.

Structural stability criteria for firefighters were achieved as all floors are provided 2 hours fire resistance rating and firefighters were able to access to all levels from a 2 hours fire rated stairway. The automatic sprinkler system, and fire rated floors and stairways would enhance safe access for search and rescue operations. The building was achieved Design Fire Scenario Nine.

6.12 Design Fire Scenario Ten (Robustness Check)

This scenario applied to areas with more than 150 people. The robustness of the design was tested by considering the design fire with each key fire safety system rendered ineffective in turn excluding fire sprinkler system and smoke detection system installed to a recognised standard. A deterministic ASET/RSET approach was used to assess the safety of a design with a fire/smoke door ineffective. Design Fire Scenario Ten were achieved. A summary of ASET and RSET for the hospital and shopping mall are provided in Table 6-19.

Table 6-19: ASET and RSET for shopping mall with a fire/smoke door ineffective

FIRE LOCATED IN ANCHOR BUILDING – 3 ON FLOOR 3 (ANCHOR BUILDING FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Anchor building - 3	2330	538	1790	433	Comply
Communicating space	>3600	672[a]	>2930	>122	Comply
Stairway	>3600	985[b]	>2620	>365	Comply
FIRE LOCATED IN RESTAURANT ON FLOOR 3 (RESTAURANT FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Restaurant	598	524	74	114	Comply
Communicating space	3090	628[a]	3060	492	Comply
Stair	>3600	941[b]	>2660	>382	Comply
FIRE LOCATED IN SMALL SHOP ON FLOOR 3 (SMALL SHOP FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Small shop	512	386	126	133	Comply
Communicating space	3190	622[a]	2570	512	Comply
Stairway	>3600	935[b]	>2670	>385	Comply
FIRE LOCATED IN COMMUNICATING SPACE ON FLOOR 2 (COMMUNICATING SPACE FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Communicating space	2260	386[a]	1870	673	Comply
Stair	>3600	1210[b]	>2390	>297	Comply

Note a: Last occupant on floor 3 to clear the floor through the communicating space to the nearest fire rated stairway

Note b: Last occupant on floor 4 to clear the building through the enclosed stairway

6.13 Summary for Case Study Building Three (Shopping Mall)

Ten design fire scenarios were applied to the building. The building complied with the performance measure of the framework because it achieved all the design fire scenarios. A summary of Design Fire Scenario One to Design Fire Scenario Ten in the shopping mall are provided in Table 6-20.

Table 6-20: Summary of design fire scenarios in the shopping mall

Design Fire Scenario	Result for the shopping mall
DSF1: Challenging Fire	Comply
DSF2: Block Exit	Comply
DSF3: Fire in Unoccupied Spaces	Comply
DSF4: Fire in Concealed Spaces	Comply
DSF5: Smouldering Fire	Comply
DSF6: Spread to Other Property	Comply
DSF7: Vertical External Fire Spread	Comply
DSF8: Interior Surface Finishes	Comply
DSF9: Fire Service Operations	Comply
DSF10: Robustness Check	Comply

7 Extended Investigation to the Framework

7.1 Introduction

Three case study buildings designed with fire protection features in accordance with the prescriptive requirements of NFPA5000 were investigated in the previous chapters. In this chapter, each case study building designed to be substantially altered from the NFPA5000 prescriptive requirements was investigated to fulfil the objective of this research. Each key fire protection feature was rendered ineffective in turn without any additional fire safety systems installed to the case study buildings. The key fire protection features are as follows:

- Automatic sprinkler system
- Automatic smoke detection system
- Interior fire/smoke separation
- Egress capacity

All three case study buildings were tested against the framework to determine whether the non-compliant buildings would remain compliant with the framework.

Note that these analyses in this chapter were only for research purposes and were not part of the framework requirements for performance-based fire design.

7.2 Ineffective Sprinkler System

Each case study building was modelled without automatic sprinkler system and would not comply with NFPA5000 prescriptive requirements. The sprinkler system or smoke detector was assumed to alert the occupants as it was the assumption from the fire modelling rules. The major effect from a failure sprinkler system was the continuous growth of fire until it reached the peak heat release rate. The basic building geometry, fire modelling rules, building materials and the design fire growth rate were described previously and were unchanged. A summary of ASET and RSET for the retail warehouse (Rack Storage Group 1 fire and Rack Storage Group 3 fire), hospital and shopping mall are provided in Table 7-1 and Table 7-2 respectively.

Table 7-1: ASET and RSET for retail warehouse (Rack Storage Group 1) fire with sprinkler system not operated

FIRE LOCATED IN RETAIL AREA (RETAIL FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Retail Area	195	383	-188	51	Not Comply
Retail Area	195	383[a]	-188	51	Not Comply
Stock Room	216	160	56	135	Comply
Drive Thru	308	217	91	142	Comply
Stairway	153	161[b]	-8	95	Not Comply
Stairway	153	166[c]	-13	92	Not Comply
Mezzanine	126	159	-33	79	Not Comply
FIRE LOCATED IN STORARE AREA (STORAGE FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Retail Area	240	436	-196	55	Not Comply
Retail Area	240	376[a]	-136	64	Not Comply
Stock Room	74	123	-49	60	Not Comply
Drive Thru	384	210	174	183	Comply
Stairway	96	124[b]	-28	77	Not Comply
Stairway	96	159[c]	-63	60	Not Comply
Mezzanine	96	152	-56	63	Not Comply
FIRE LOCATED IN DRIVE THRU (DRIVE THRU FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Retail Area	464	438	26	106	Comply
Retail Area	464	378[a]	86	123	Comply
Stock Room	464	155	309	299	Comply
Drive Thru	96	152	-56	63	Not Comply
Stairway	272	156[b]	116	174	Comply
Stairway	272	161[c]	111	169	Comply
Mezzanine	144	154	-10	94	Not Comply
FIRE LOCATED IN MEZZANINE (MEZZANINE FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Retail Area	> 1800	505	> 1300	> 356	Comply
Retail Area	> 1800	415[a]	> 1380	> 433	Comply
Stock Room	> 1800	222	> 1580	> 811	Comply
Drive Thru	> 1800	279	> 1520	> 645	Comply
Stairway	143	223[b]	-80	64	Not Comply
Stairway	143	198[c]	-55	72	Not Comply
Mezzanine	96	191	-95	50	Not Comply

Note a: Some of the occupants in mezzanine travelled to the retail area through the open stairway to the outside

Note b: Some of the occupants in the storage area to clear the building through the enclosed stairway

Note c: Some of the occupants in the mezzanine to clear the building through the enclosed stairway

Table 7-2: ASET and RSET for retail warehouse (Rack Storage Group 3 fire) with sprinkler system not operated

FIRE LOCATED IN RETAIL AREA (RETAIL FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Retail Area	256	453	-197	57	Not Comply
Retail Area	256	453[a]	-197	57	Not Comply
Stock Room	280	230	50	122	Comply
Drive Thru	369	287	82	129	Comply
Stairway	223	231[b]	-8	97	Not Comply
Stairway	223	236[c]	-13	94	Not Comply
Mezzanine	193	229	-36	84	Not Comply
FIRE LOCATED IN STORARE AREA (STORAGE FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Retail Area	281	399	-118	70	Not Comply
Retail Area	281	439[a]	-158	64	Not Comply
Stock Room	132	186	-54	71	Not Comply
Drive Thru	430	273	157	158	Comply
Stairway	143	187[b]	-54	71	Not Comply
Stairway	143	222[c]	-79	64	Not Comply
Mezzanine	168	215	-47	78	Not Comply
FIRE LOCATED IN DRIVE THRU (DRIVE THRU FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Retail Area	520	502	18	104	Comply
Retail Area	520	442[a]	78	118	Comply
Stock Room	519	219	300	237	Comply
Drive Thru	145	216	-71	67	Not Comply
Stairway	337	220[b]	117	153	Comply
Stairway	337	225[c]	112	150	Comply
Mezzanine	191	218	-27	88	Not Comply
FIRE LOCATED IN MEZZANINE (MEZZANINE FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Retail Area	>1800	505	> 1300	> 356	Comply
Retail Area	>1800	415[a]	> 1380	> 433	Comply
Stock Room	> 1800	222	> 1580	> 811	Comply
Drive Thru	>1800	279	> 1520	> 645	Comply
Stairway	143	223[b]	-80	64	Not Comply
Stairway	143	198[c]	-55	72	Not Comply
Mezzanine	96	191	-95	50	Not Comply

Note a: Some of the occupants in mezzanine travelled to the retail area through the open stairway to the outside

Note b: Some of the occupants in the storage area to clear the building through the enclosed stairway

Note c: Some of the occupants in the mezzanine to clear the building through the enclosed stairway

Table 7-3: ASET and RSET for hospital with sprinkler system not operated

FIRE LOCATED IN CAFETERIA (CAFETERIA FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Cafeteria	96	440	-344	22	Not Comply
Corridor -2	1070	502[a]	570	214	Comply
Stairway	> 7200	2130[b]	> 5070	> 338	Comply
FIRE LOCATED IN PHYSIOTHERAPY (PHYSIOTHERAPY FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Physiotherapy	143	264	-121	54	Not Comply
Corridor-2	283	454[c]	-171	62	Not Comply
Corridor-2	283	514[a]	-231	55	Not Comply
Stairway	> 3000	2120[b]	> 880	> 142	Comply
FIRE LOCATED IN LABORATORY (LABORATORY FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Laboratory	170	255	-85	67	Not Comply
Corridor-1	318	264[d]	54	120	Comply
Corridor-2	> 7200	2010[e]	> 5190	> 358	Comply
Stairway	> 7200	2140[b]	> 5060	> 336	Comply
FIRE LOCATED IN HOSTEL (HOSTEL FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Hostel	122	143	-21	85	Not Comply
Corridor-1	279	169[f]	110	165	Comply
Corridor-2	> 7200	1930[g]	> 5270	374	Comply
Stairway	> 7200	2030[b]	> 5170	351	Comply

Note a: Last occupant on floor 1 to clear the building through the corridor-2 to the outside

Note b: Last sleeping occupant on floor 4 to clear the building through the enclosed stairway

Note c: Physiotherapy occupant on floor 1 to clear the building through the corridor-2 to the outside

Note d: Laboratory occupant on floor 2 to clear the floor through the corridor-1 to the enclosed stairway

Note e: Last occupant on floor 2 to clear the floor to the enclosed stairway through the corridor-2

Note f: Hostel occupant on floor 3 to clear the floor through the corridor-1 to the enclosed stairway

Note g: Hostel occupant on floor 3 to clear the floor to the enclosed stairway through the corridor-2

Table 7-4: ASET and RSET for shopping mall with sprinkler system not operated

FIRE LOCATED IN ANCHOR BUILDING – 3 ON FLOOR 3 (ANCHOR BUILDING FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Anchor building - 3	477	538	-61	89	Not Comply
Communicating space	876	672[a]	204	130	Comply
Stair	3000	985[b]	2015	305	Comply
FIRE LOCATED IN RESTAURANT ON FLOOR 3 (RESTAURANT FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Restaurant	185	524	-339	35	Not Comply
Communicating space	649	628[a]	21	103	Comply
Stairway	3000	941[b]	2059	319	Comply
FIRE LOCATED IN SMALL SHOP ON FLOOR 3 (SMALL SHOP FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Small shop	160	386	-226	41	Not Comply
Communicating space	623	622[a]	1	100	Comply
Stairway	> 3000	935[b]	> 2065	> 321	Comply
FIRE LOCATED IN COMMUNICATING SPACE ON FLOOR 2 (COMMUNICATING SPACE FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Anchor building - 3	433	821	-388	53	Not Comply
Communicating space	431	895[a]	-464	48	Not Comply
Stairway	> 3000	1200[b]	> 1790	> 249	Comply

Note a: Last occupant on floor 3 to clear the floor through communicating space to the nearest fire rated stairway
Note b: Last occupant on floor 4 to clear the building through the enclosed stairway

7.3 Ineffective Smoke Detection System

The retail warehouse and shopping mall were not required to install smoke detection system in accordance with NFPA5000 prescriptive requirements. Apart from the hostel in the hospital, smoke detection system was not a required system in the cafeteria, physiotherapy and laboratory to meet the prescriptive requirements. In this section, smoke detection system was not modelled and the quick response sprinkler system in the hostel was assumed to alert the occupants. The hospital would not comply with NFPA5000 prescriptive requirements and no longer provide early warning to sleeping occupants in the hostel. The basic building geometry, building materials and the design fire growth rate were described previously and were unchanged. A summary of ASET and RSET for a fire located in the hostel area is provided in Table 7-5.

Table 7-5: ASET and RSET for hostel fire with smoke detection system not operated

FIRE LOCATED IN HOSTEL (HOSTEL FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Hostel	916	206	710	445	Comply
Corridor - 1	1850	232[a]	1618	797	Comply
Corridor-2	> 7200	1990[b]	> 5210	> 362	Comply
Stairway	> 7200	2112[c]	> 5090	> 341	Comply

Note a: Hostel occupant on floor 3 to clear the floor through the corridor-1 to the enclosed stairway
Note b: Hostel occupant on floor 3 to clear the floor to the enclosed stairway through the corridor-2
Note c: Last sleeping occupant on floor 4 to clear the building through the enclosed stairway

7.4 Ineffective Interior Fire/Smoke Separations

In accordance with the prescriptive requirements of NFPA5000, there were no requirements for interior fire/smoke separations or self-closing devices in the retail warehouse and therefore the retail warehouse was not analysed in this section. In the following analyses, all interior walls were assumed to have leakage areas and all doors were modelled to be open. The hospital and shopping would not comply with NFPA5000 prescriptive requirements and the spread of fire/smoke would not be limited. The basic building geometry, building materials and the design fires were described previously and were unchanged. The active fire protection systems were functioned as intended by NFPA5000 prescriptive design. A summary of ASET and RSET for the hospital and shopping mall are provided in Table 7-6 and Table 7-7.

Table 7-6: ASET and RSET for hospital without any interior fire/smoke separations

FIRE LOCATED IN CAFETERIA (CAFETERIA FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Cafeteria	818	440	378	187	Comply
Corridor-2	1640	502[a]	1140	328	Comply
Stairway	2430	2130[b]	300	114	Comply
FIRE LOCATED IN PHYSIOTHERAPY (PHYSIOTHERAPY FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Physiotherapy	1140	264	776	313	Comply
Corridor-2	2170	454[c]	1710	447	Comply
Corridor-2	2170	514[a]	1650	421	Comply
Stairway	2770	2120[b]	646	130	Comply
FIRE LOCATED IN LABORATORY (LABORATORY FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**

Laboratory	992	255	740	394	Comply
Corridor-1	1370	264[d]	1110	525	Comply
Corridor-2	1820	2010[e]	-190	91	Not Comply
Stairway	2380	2140[b]	240	111	Comply
FIRE LOCATED IN HOSTEL (HOSTEL FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Hostel	1230	143	1090	860	Comply
Corridor-1	1690	169[f]	1520	1000	Comply
Corridor-2	2360	1930[g]	430	122	Comply
Stairway	2980	2030[b]	950	145	Comply

Note a: Last occupant on floor 1 to clear the building through the corridor-2 to the outside

Note b: Last sleeping occupant on floor 4 to clear the building through the enclosed stairway

Note c: Physiotherapy occupant on floor 1 to clear the building through the corridor-2 to the outside

Note d: Laboratory occupant on floor 2 to clear the floor through the corridor-1 to the enclosed stairway

Note e: Last occupant on floor 2 to clear the floor to the enclosed stairway through the corridor-2

Note f: Hostel occupant on floor 3 to clear the floor through the corridor-1 to the enclosed stairway

Note g: Hostel occupant on floor 3 to clear the floor to the enclosed stairway through the corridor-2

Table 7-7: ASET and RSET for shopping mall without any interior fire/smoke separations

FIRE LOCATED IN ANCHOR BUILDING – 3 ON FLOOR 3 (ANCHOR BUILDING FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Anchor building - 3	2140	538	1600	398	Comply
Communicating space	> 2990	672[a]	> 2320	445	Comply
Stairway	> 2990	985[b]	> 2010	304	Comply
FIRE LOCATED IN RESTAURANT ON FLOOR 3 (RESTAURANT FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Restaurant	598	524	74	114	Comply
Communicating space	3150	628[a]	2520	502	Comply
Stair	> 3600	941[b]	> 2660	383	Comply
FIRE LOCATED IN SMALL SHOP ON FLOOR 3 (SMALL SHOP FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Small shop	512	386	126	133	Comply
Communicating space	2360	622[a]	1740	379	Comply
Stairway	3600	935[b]	2670	385	Comply
FIRE LOCATED IN COMMUNICATING SPACE ON FLOOR 2 (COMMUNICATING SPACE FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Communicating space	2170	386[a]	1780	562	Comply
Stair	3130	1210[b]	1920	259	Comply

Note a: Last occupant on floor 3 to clear the floor through the communicating space to the nearest fire rated stairway

Note b: Last occupant on floor 4 to clear the building through the enclosed stairway

7.5 Reduced Exit(s)

To comply with NFPA5000 prescriptive requirements, each room of fire origin in the previous chapters was provided with two exits, except retail area in retail warehouse, small shop, anchor building – 3 and communicating space in shopping mall. In the retail area and anchor building – 3, there were three exits available for the occupants in each area. In the communicating space, there were seven fire-isolated exit stairways available for the occupants. The small shop provided only with single exit and it was not analysed.

In this section, a fire was assumed to be located near one or more escape route(s) and occupants were unable to egress through the route(s). In the following analyses, the number of exits in the room of fire origin was reduced until a single exit remained. The retail warehouse, hospital and shopping would not comply with NFPA5000 prescriptive requirements and would not provide with sufficient exits to enable safe egress in an event of a fire. The building geometry, building materials and the design fires were described previously and were unchanged. All active and passive fire protection systems functioned as intended by NFPA5000 prescriptive design. A summary of ASET and RSET for retail warehouse (Rack Storage Group 1 fire), hospital and shopping mall with reduced exit(s) are shown in Table 7-8 to Table 7-10.

Table 7-8: ASET and RSET for retail warehouse (Rack Storage Group 1 fire) with reduced exit(s)

FIRE LOCATED IN RETAIL AREA (RETAIL FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Retail Area	741	506	235	146	Comply
Retail Area	741	875[a]	-134	85	Not Comply
Retail Area	741	383[b]	358	193	Comply
Stock Room	523	160	363	327	Comply
Drive Thru	1610	217	1390	742	Comply
Stairway	> 1800	161[c]	> 1640	> 1120	Comply
Stairway	> 1800	166[d]	> 1630	> 1080	Comply
Mezzanine	> 1800	159	> 1740	> 1200	Comply
FIRE LOCATED IN STORARE AREA (STORAGE FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Retail Area	1180	436	748	272	Comply
Retail Area	1180	376[b]	808	315	Comply
Stock Room	346	162	184	214	Comply

Drive Thru	> 1800	210	> 1590	> 857	Comply
Stairway	897	162[c]	735	554	Comply
Stairway	897	159[d]	738	564	Comply
Mezzanine	> 1800	152	> 1650	> 1180	Comply
FIRE LOCATED IN DRIVE THRU (DRIVE THRU FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Retail Area	1730	438	1290	394	Comply
Retail Area	1730	378[b]	1350	456	Comply
Stock Room	> 1800	155	1650	1160	Comply
Drive Thru	290	174	116	167	Comply
Stairway	> 1800	156[c]	> 1640	> 1150	Comply
Stairway	> 1800	161[d]	> 1640	> 1120	Comply
Mezzanine	> 1800	154	> 1650	> 1170	Comply
FIRE LOCATED IN MEZZANINE (MEZZANINE FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Retail Area	> 1790	505	> 1285	> 354	Comply
Retail Area	> 1790	444[b]	> 1350	> 404	Comply
Stock Room	> 1790	222	> 1570	> 806	Comply
Drive Thru	> 1790	279	> 1510	> 642	Comply
Stairway	1216	223[c]	993	545	Comply
Stairway	1216	231[d]	985	526	Comply
Mezzanine	896	220	676	407	Comply

Note a: Reduced two exits in retail area

Note b: Some of the occupants in mezzanine travelled to the retail area through the open stairway to the outside

Note c: Some of the occupants in the storage area to clear the building through the enclosed stairway

Note d: Some of the occupants in the mezzanine to clear the building through the enclosed stairway

Table 7-9: ASET and RSET for hospital with reduced exit

FIRE LOCATED IN CAFETERIA (CAFETERIA FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Cafeteria	881	678	203	130	Comply
Corridor-2	> 7200	502[a]	> 6700	> 1430	Comply
Stairway	> 7200	2130[b]	> 5070	> 338	Comply
FIRE LOCATED IN PHYSIOTHERAPY (PHYSIOTHERAPY FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Physiotherapy	1150	316	834	364	Comply
Corridor-2	2960	503[c]	3450	588	Comply
Corridor-2	2960	561[a]	2400	527	Comply
Stairway	2060	2140[b]	814	138	Comply

FIRE LOCATED IN LABORATORY (LABORATORY FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Laboratory	1080	328	752	329	Comply
Corridor - 1	1990	346[d]	1644	575	Comply
Corridor-2	> 7200	2010[e]	> 5190	> 358	Comply
Stairway	> 7200	2140[b]	> 5060	> 336	Comply
FIRE LOCATED IN HOSTEL (HOSTEL FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Hostel	916	162	754	565	Comply
Corridor - 1	1850	182[f]	1668	1016	Comply
Corridor-2	> 7200	1930[g]	> 5240	> 372	Comply
Stairway	> 7200	2050[b]	> 5120	> 350	Comply

Note a: Last occupant on floor 1 to clear the building through the corridor-2 to the outside

Note b: Last sleeping occupant on floor 4 to clear the building through the enclosed stairway

Note c: Physiotherapy occupant on floor 1 to clear the building through the corridor-2 to the outside

Note d: Laboratory occupant on floor 2 to clear the floor through the corridor-1 to the enclosed stairway

Note e: Last occupant on floor 2 to clear the floor to the enclosed stairway through the corridor-2

Note f: Hostel occupant on floor 3 to clear the floor through the corridor-1 to the enclosed stairway

Note g: Hostel occupant on floor 3 to clear the floor to the enclosed stairway through the corridor-2

Table 7-10: ASET and RSET for shopping mall with reduced exit(s)

FIRE LOCATED IN ANCHOR BUILDING – 3 ON FLOOR 3 (ANCHOR BUILDING FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Anchor building - 3	2320	654	1670	354	Comply
Anchor building - 3	2320	999[a]	1320	232	Comply
Communicating space	> 3600	672[b]	> 2928	536	Comply
Stairway	> 3600	985[c]	> 2615	365	Comply
FIRE LOCATED IN RESTAURANT ON FLOOR 3 (RESTAURANT FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Restaurant	608	787	-179	77	Not Comply
Communicating space	3100	628[b]	2470	494	Comply
Stairway	3580	941[c]	2640	380	Comply
FIRE LOCATED IN SMALL SHOP ON FLOOR 3 (SMALL SHOP FIRE)					
Room	**ASET (s)**	**RSET (s)**	**Margin (s)**	**Margin (%)**	**Scenario Result**
Anchor building - 3	3390	821	2569	413	Comply
Communicating space	3180	622[b]	2560	512	Comply
Stairway	3600	1210[c]	2390	298	Comply
FIRE LOCATED IN COMMUNICATING SPACE ON FLOOR 2 (COMMUNICATING SPACE FIRE)					

Room	ASET (s)	RSET (s)	Margin (s)	Margin (%)	Scenario Result
Anchor building - 3	3390	821	2570	413	Comply
Communicating space	2250	946[b]	1300	238	Comply
Communicating space	2250	1020[d]	1230	221	Comply
Communicating space	2250	1130[e]	1120	200	Comply
Communicating space	2250	1300[f]	2140	172	Comply
Communicating space	2250	1660[g]	587	135	Comply
Communicating space	2250	2730[h]	-495	82	Not Comply
Stairway	3600	1210[c]	2390	298	Comply

Note a: Reduced two means of egress in Anchor building-3

Note b: Last occupant on floor 3 to clear floor 3 through the communicating space to the nearest fire rated stairway

Note c: Last occupant on floor 4 to clear the building through the enclosed stairway

Note d: Last occupant on floor 3 to clear the floor through the communicating space (reduced two exits) to the nearest fire rated stairway

Note e: Last occupant on floor 3 to clear the floor through the communicating space (reduced three exits) to the nearest fire rated stairway

Note f: Last occupant on floor 3 to clear the floor through the communicating space (reduced four exits) to the nearest fire rated stairway

Note g: Last occupant on floor 3 to clear the floor through the communicating space (reduced five exits) to the nearest fire rated stairway

Note h: Last occupant on floor 3 to clear the floor through the communicating space (reduced six exits) to the nearest fire rated stairway

7.6 Summary for Extended Investigation to the Framework

To investigate the performance of the framework, three case study buildings designed to be substantially altered from the NFPA5000 prescriptive requirements were tested against the Design Fire Scenario One (Challenging Fire) (DFS1). The DFS1 represents a challenging fire and provides a credible worst case scenario to challenge the fire protection features of the NFPA5000 non-compliant buildings. The results were summarised as below:

- In section 7.2 (Ineffective Sprinkler System), all case study building were not installed with a required automatic sprinkler system to control a fire. The NFPA5000 non-compliance buildings did not comply with DFS1. The framework would not allow the non-compliance.
- In section 7.3 (Ineffective Smoke Detection System), Hostel in the hospital was not installed with a required smoke detection system to provide an early warning system to the sleeping occupants. The NFPA5000 non-compliance hospital complied with DFS1. However, Design Fire Scenario Fire (Smouldering Fire) would require a smoke detection system in the Hostel to alert sleeping occupants. The framework would not allow the non-compliance.
- In section 7.4 (Ineffective Interior Fire/Smoke Separations), the hospital and shopping mall were not provided with any internal fire/smoke separations to limit the spread of fire and smoke. The NFPA5000 non-compliance hospital and shopping mall complied with DFS1, except for Laboratory Fire in the hospital. The framework would accept the non-compliances.
- In section 7.5 (Reduced Exit(s)), all case study buildings were not provided with sufficient exits in the room of fire origin to enable safe egress. The NFPA5000 non-compliance buildings complied with DFS1, except for Retail Fire (Single exit remained) in the retail warehouse, Restaurant Fire (Single exit remained) in the shopping mall and Communication Space Fire (Single exit remained) in the shopping mall. However, Design Fire Scenario Two (Blocked Exit) (DFS2) would require at least two exits in an open path or horizontal safe path serving

more than 50 people or a vertical safe path serving more than 150 people (not sprinkler protected) or 250 people (sprinkler protected) and therefore the Cafeteria Fire, Physiotherapy Fire, Laboratory Fire and Anchor Building – 3 Fire (Single exit remained) did not comply with DFS2. The framework would accept the non-compliance in the retail area (two exits remained), storage area, drive thru area, mezzanine in the retail warehouse, hostel in the hospital, anchor building – 3 (two exits remained) and communicating space (two exits remained).

An overall summary of DFS1 results for all case study buildings were presented in Appendix C. The appendix included tables and figures to show the values of ASET and RSET as well as the margin of ASET and RSET at the room of fire origin. The tables and figures would provide a good comparison between the NFPA5000 compliance and non-compliance buildings using the values and methodology described in the framework.

8 Fire Dynamics Simulator Analysis

8.1 Introduction

In this chapter, Fire Dynamics Simulator (FDS) was used to analyse and to compare some of the DFS1 results from BRANZFIRE in chapters 4 to 7. Two fire locations from each NFPA5000 compliance building and two fire locations from each NFPA5000 non-compliance building were selected to investigate in the following sections. The fire locations are listed below:

- Storage area and drive thru area in the retail warehouse
- Physiotherapy and hostel in the hospital
- Communicating space, restaurant and anchor building – 3 in the shopping mall

The buildings were modelled in FDS using the same construction materials as specified in BRANZFIRE and the simulated results from FDS was displayed using a visualisation program called Smokeview [25].

8.2 Description of Fire Modelling in FDS

All FDS models were identical to the actual building design and were modelled in accordance with the design modelling rules described in the framework. The plan view and the elevation view of the retail warehouse simulated by FDS are shown in Figure 8-1 and Figure 8-2. The cell size was 0.25 m by 0.25 m by 0.25 m and the total number of cells in the model was approximately 2.1 million. The other FDS models are presented in Appendix D1.

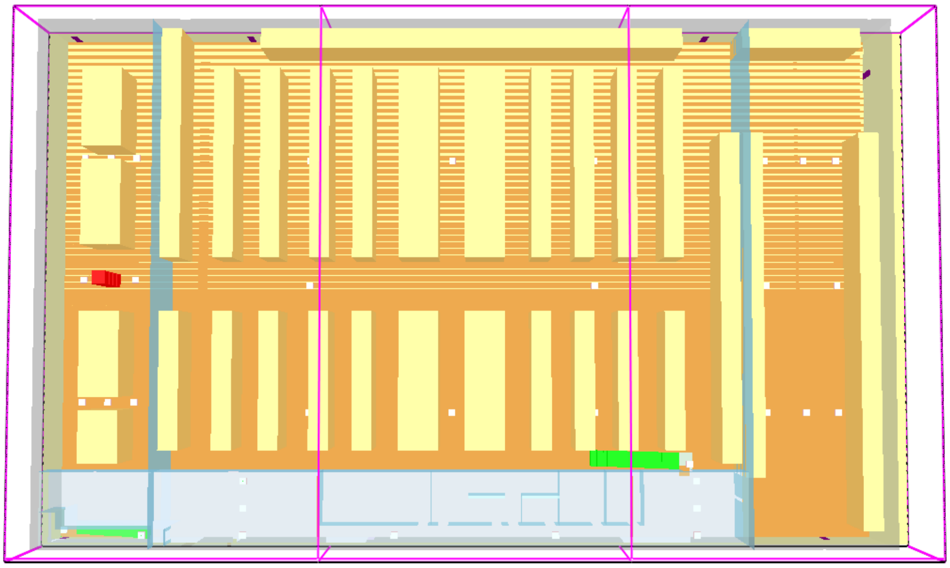

Figure 8-1: Plan view of the retail warehouse

Figure 8-2: Elevation view of the retail warehouse

8.3 Design Fire

The design fire was applied to the retail warehouse based on the requirement in the framework, as discussed in section 2.3.1. The fire was located in the storage area and was controlled by the sprinkler system. The peak heat release rate of the fire was 6.2 MW at 52 s where the standard response sprinkler system was activated and was obtained from FDS. The fire became limited by ventilation after 300s (Figure 8-3) and the heat release rate reduced. According to the fire modelling rules, windows were assumed to break when the heat release rate dropped. Since there was no window in the area, this rule was not applied. The design fire growth rates peak heat release rate and time to reach 500^{o}C (or when the Heat Release Rate drop) for the other FDS models are detailed in Table 8-1 and Appendix D2.

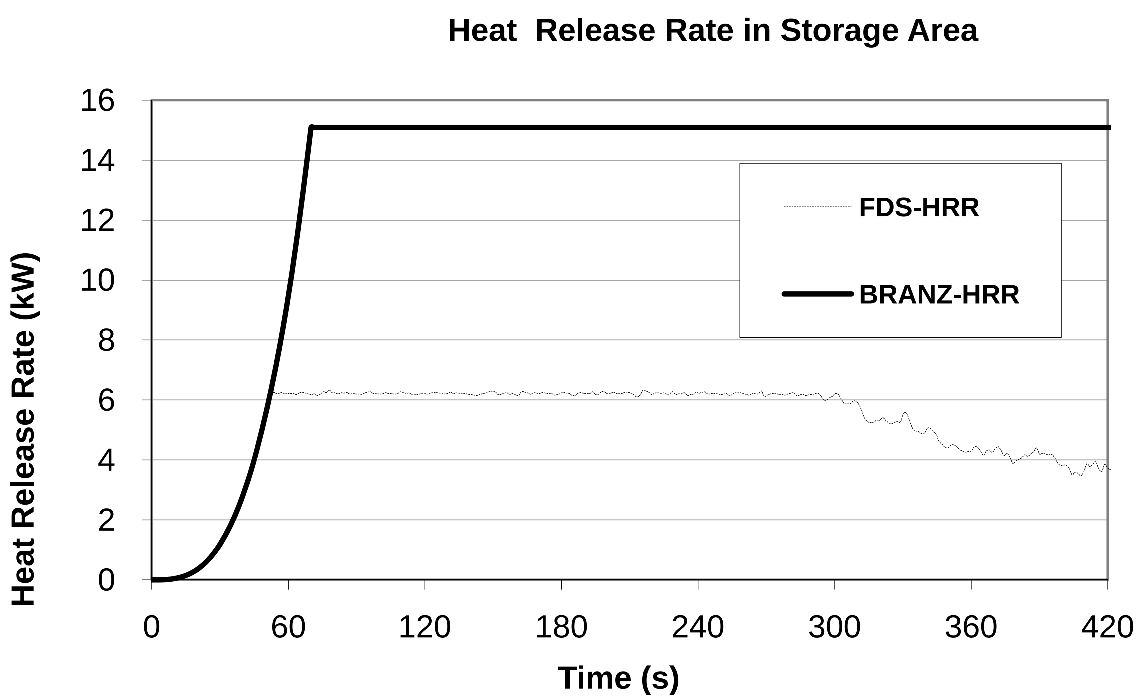

Figure 8-3: Heat release rate curves for storage fire where sprinkler system was successfully operated

Table 8-1: Design fires from BRANZFIRE modelling

Fire Location	Sprinkler Protected/Activation(s)		Fire Growth Rate (kW)	Time to reach 500°C or when the Heat Release Rate reduces (s)		Peak Heat Release Rate (MW)	
	BRANZFIRE	FDS		BRANZFIRE	FDS	BRANZFIRE	FDS
Storage area	70	53	$0.044t^3$	Not reached	300	15.1	6.2
Storage area	Not sprinkler protected		$0.044t^3$	656	80	20.0	20.0
Drive thru area	72	53	$0.044t^3$	Not reached	360	16.4	6.2
Drive thru area	Not sprinkler protected		$0.044t^3$	544	120	20.0	20.0
Physiotherapy	153	148	$0.047t^2$	Not reached	Not reached	1.1	1.0
Physiotherapy	Not sprinkler protected		$0.047t^2$	640	430	20.0	20.0
Hostel	59	83	$0.047t^2$	1980	>1200	0.7	0.7
Hostel	Not sprinkler protected		$0.047t^2$	450	365	20.0	20.0
Communicating Space	467	316	$0.047t^2$	Not reached	Not reached	10.0	4.7
Communicating Space	Not sprinkler protected		$0.047t^2$	Not reached	Not reached	20.0	20.0
Restaurant	200	174	$0.047t^2$	1370	>720	1.9	1.4
Anchor building – 3	Not sprinkler protected		$0.047t^2$	Not reached	1190	20.0	20.0

8.4 FDS Modelling Results to determine ASET

Visibility devices, FED(CO) devices, temperature devices, gauge heat flux devices and radiative heat flux devices were located 2.0 m above floor. The locations of devices are shown in Figure 8-4. The devices were located at half the distance between the fire and the nearest wall. FDS did not obtain FED (thermal) measurement directly and therefore the results from temperature device, gauge heat flux device and radiative heat flux device were obtained and were used to calculate the FED (thermal) in accordance with ISO standard [31]. The equations to calculate the FED (thermal) were given below. The results of visibility, FED(CO) and FED(thermal) obtained from FDS are shown in Figure 8-5 to Figure 8-8. The device locations and the results of the other FDS models are detailed in Appendix D3.

$$t_{rad} = 4.2q^{-1.9} \qquad \text{Equation 10}$$

$$t_{conv} = (4.1\times10^{8})T^{-3.61} \qquad \text{Equation 11}$$

$$X_{FED} = \sum_{t_1}^{t_2}\left(\frac{1}{t_{rad}} + \frac{1}{t_{conv}}\right)\Delta t \qquad \text{Equation 12}$$

where

q is the radiant heat flux (kW/m^2)

T is the temperature (^{o}C)

t_{rad} is the time to experiencing pain due to radiant heat (minutes)

t_{conv} is the time to experiencing pain due to convected heat (minutes)

Δt is the time increment (minutes)

X_{FED} is the total fractional effective dose of heat

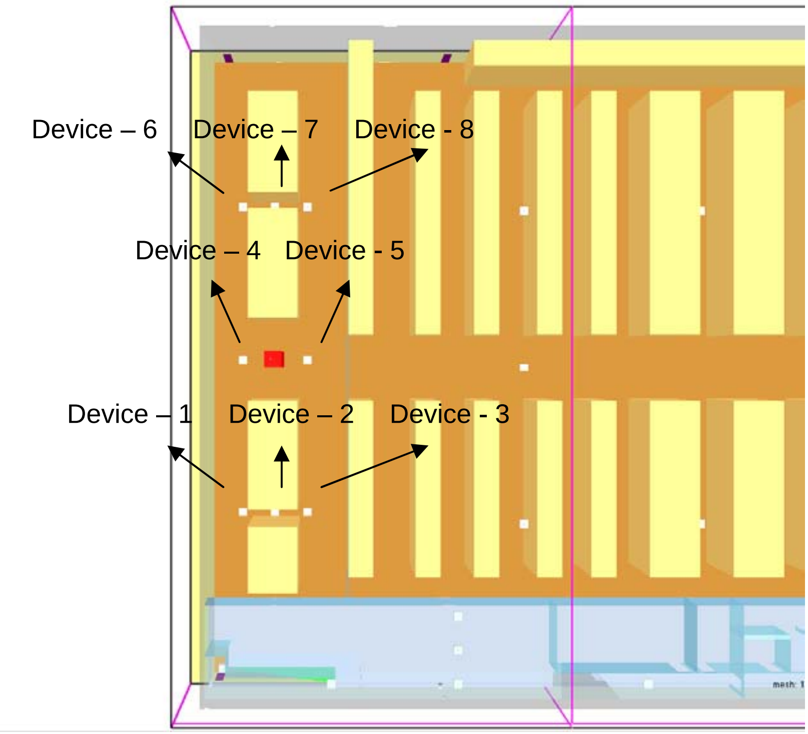

Figure 8-4: Device locations for storage fire where sprinkler system was successfully operated

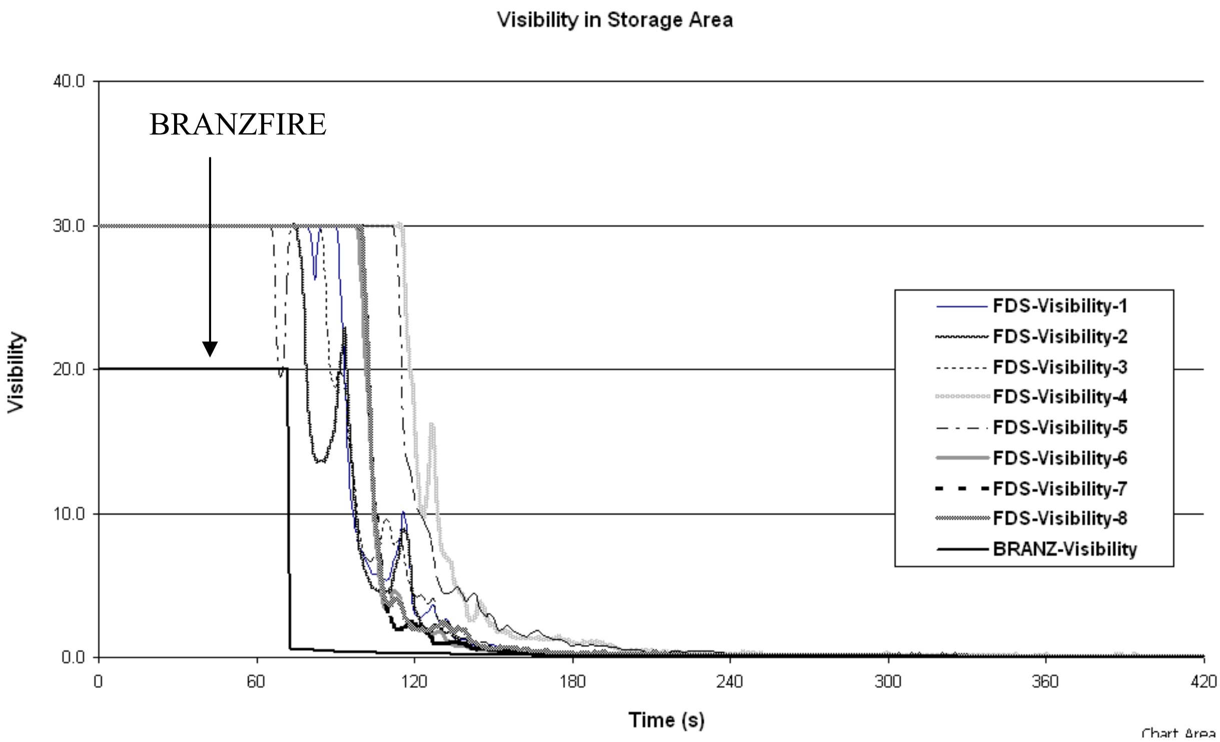

Figure 8-5: Visibility curves for storage fire where sprinkler system was successfully operated

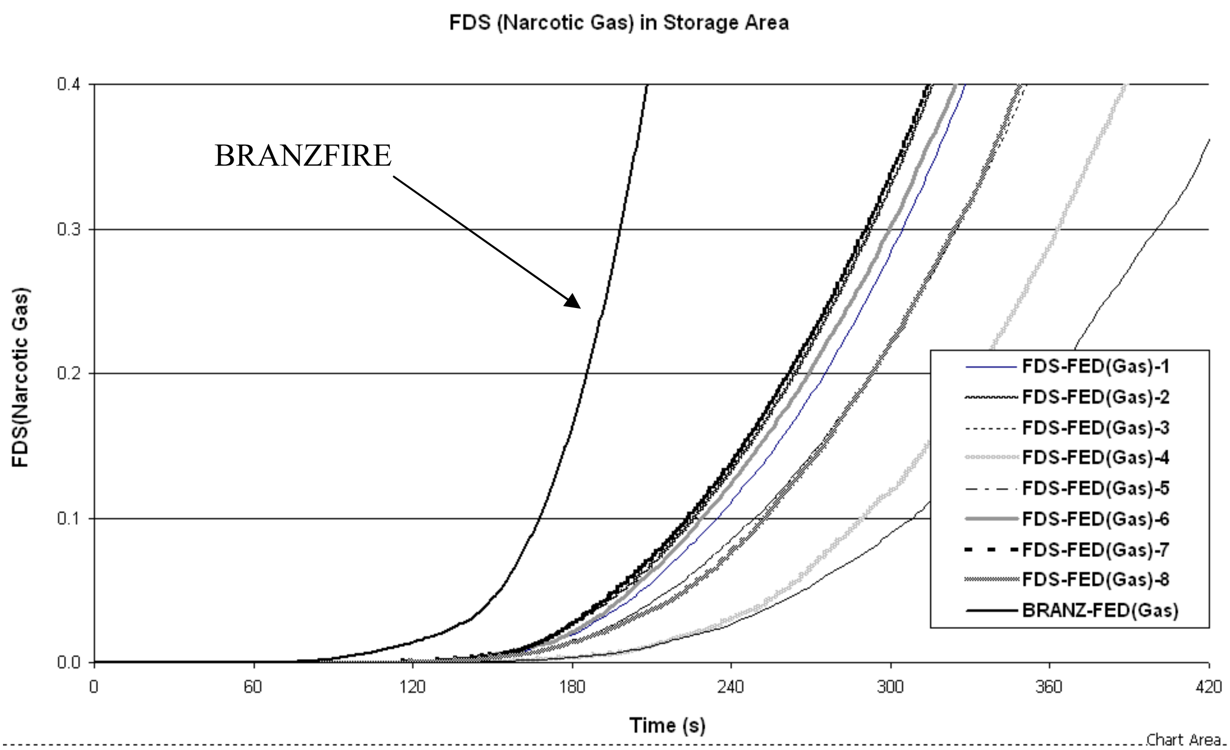

Figure 8-6: FED(CO) curves for storage fire where sprinkler system was successfully operated

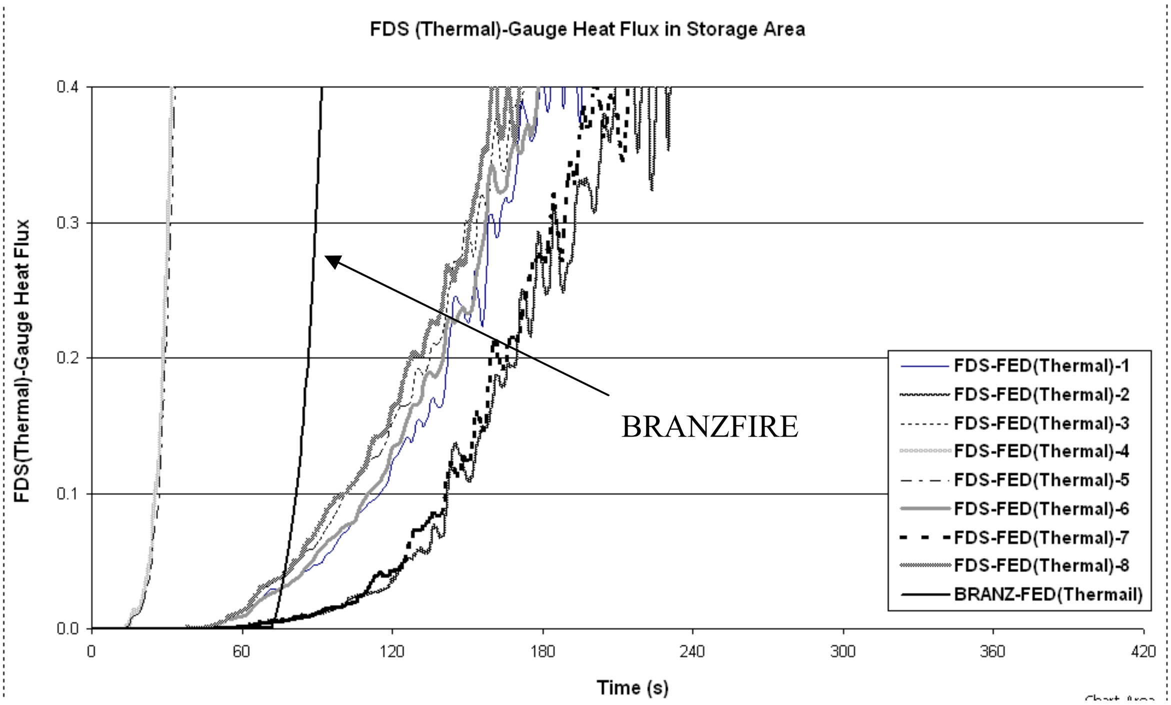

Figure 8-7: FED thermal curves from gauge heat flux for storage fire where sprinkler system was successfully operated

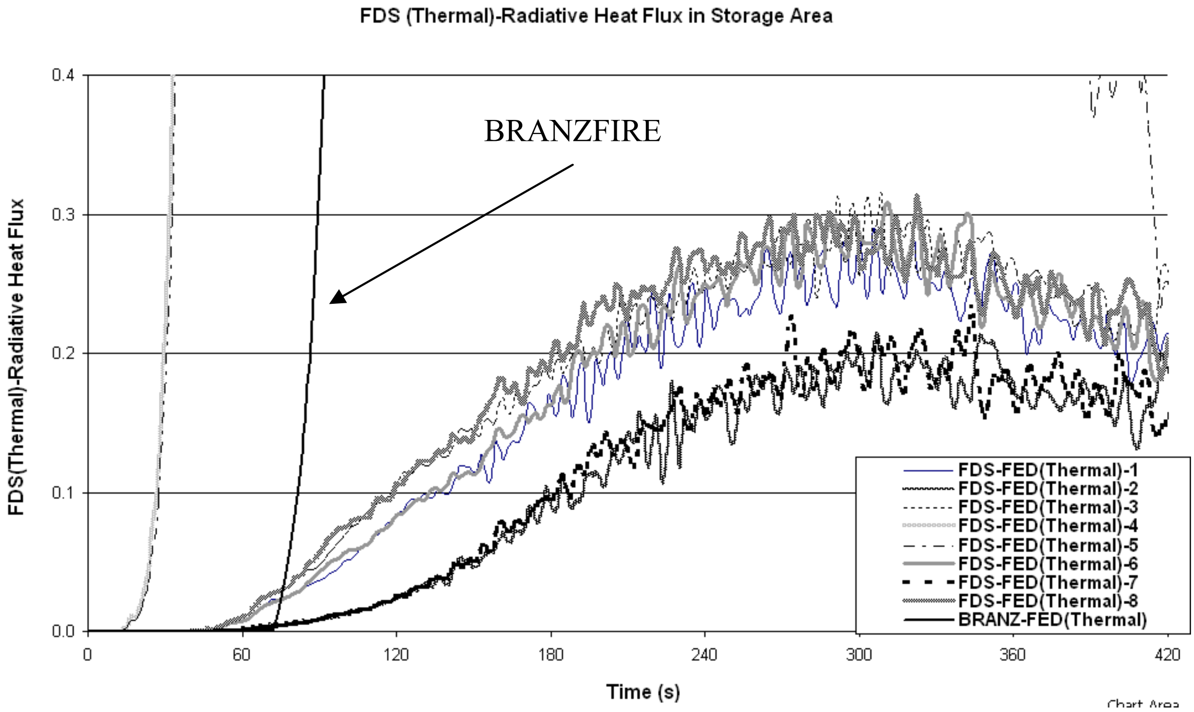

Figure 8-8: FED thermal curves from radiative heat flux for storage fire where sprinkler system was successfully operated

The tenability criteria including visibility less than 10 m, FED(CO) exceeding 0.3, FED thermal from gauge heat flux exceeding 0.3, and FED thermal from radiative heat flux exceeding 0.3 are summarised in following tables. The results were measured from the devices in different fire locations. Table 8-2 list the results from BRANZFIRE and FDS in NFPA5000 compliance buildings where **Red** represents a higher number (FDS result is larger than BRANZFIRE result), **Green** represents a lower number (FDS result is smaller than BRANZFIRE result). The results from BRANZFIRE and FDS in NFPA5000 non-compliance buildings are summarized in Table 8-3.

Table 8-2: Results from FDS in NFPA5000 compliance buildings (Sprinkler Protected)

Fire Located in Storage Area (Sprinkler Protected)				
Device	**Visibility**	**FED (CO)**	**FED (Thermal) from Gauge Heat Flux**	**FED (Thermal) from Radiative Heat Flux**
BRANZFIRE	74s	346s	90s	
FDS Device - 1	116s	304s	164s	>1300s
FDS Device - 2	98s	293s	194s	>1300s
FDS Device - 3	98s	325s	155s	>1300s
FDS Device - 4	129s	363s	31s	>1300s
FDS Device - 5	121s	401s	33s	>1300s
FDS Device - 6	105s	300s	157s	>1300s
FDS Device - 7	105s	290s	190s	>1300s
FDS Device - 8	105s	325s	151s	1133s
Fire Located in Drive Thru Area (Sprinkler Protected)				
Device	**Visibility**	**FED (CO)**	**FED (Thermal) from Gauge Heat Flux**	**FED (Thermal) from Radiative Heat Flux**
BRANZFIRE	83s	290s	99s	
FDS Device - 1	121s	464s	230s	>1136
FDS Device - 2	133s	436s	209s	>1136
FDS Device - 3	137s	446s	246s	>1136
FDS Device - 4	167s	473s	35s	>1136
FDS Device - 5	155s	446s	34s	>1136
FDS Device - 6	137s	413s	246s	>1136
FDS Device - 7	143s	450s	214s	>1136
FDS Device - 8	142s	450s	234s	>1136
Fire Located in Physiotherapy (Sprinkler Protected)				
Device	**Visibility**	**FED (CO)**	**FED (Thermal) from Gauge Heat Flux**	**FED (Thermal) from Radiative Heat Flux**
BRANZFIRE	143s	1140s	454s	
FDS Device - 1	48s	732s	>1200	>1200
FDS Device - 2	36s	718s	427s	>1200
FDS Device - 3	53s	718s	>1200	>1200
FDS Device - 4	41s	730s	>1200	>1200
FDS Device - 5	40s	725s	>1200	>1200
FDS Device - 6	53s	727s	>1200	>1200
FDS Device - 7	38s	718s	473s	>1200
FDS Device - 8	53s	730s	>1200	>1200

Fire Located in Hostel (Sprinkler Protected)				
Device	**Visibility**	**FED (CO)**	**FED (Thermal) from Gauge Heat Flux**	**FED (Thermal) from Radiative Heat Flux**
BRANZFIRE	122s	916s	545s	
FDS Device - 1	64s	1067s	> 5800s	> 5800s
FDS Device - 2	70s	1056s	> 5800s	> 5800s
FDS Device - 3	64s	1056s	> 5800s	> 5800s
FDS Device - 4	47s	1056s	> 5800s	> 5800s
FDS Device - 5	47s	1032s	> 5800s	> 5800s
FDS Device - 6	64s	1056s	> 5800s	> 5800s
FDS Device - 7	70s	1090s	> 5800s	> 5800s
FDS Device - 8	64s	1056s	> 5800s	> 5800s

Fire Located in Communicating Space (Sprinkler Protected)				
Device	**Visibility**	**FED (CO)**	**FED (Thermal) from Gauge Heat Flux**	**FED (Thermal) from Radiative Heat Flux**
BRANZFIRE	431s	2250s	838s	
FDS Device - 1	262s	1633s	> 1800s	> 1800s
FDS Device - 2	269s	1633s	> 1800s	> 1800s
FDS Device - 3	253s	1586s	> 1800s	> 1800s
FDS Device - 4	734s	1702s	> 1800s	> 1800s
FDS Device - 5	734s	1596s	> 1800s	> 1800s
FDS Device - 6	237s	1621s	> 1800s	> 1800s
FDS Device - 7	292s	1679s	> 1800s	> 1800s
FDS Device - 8	253s	1633s	> 1800s	> 1800s

Fire Located in Restaurant (Sprinkler Protected)				
Device	**Visibility**	**FED (CO)**	**FED (Thermal) from Gauge Heat Flux**	**FED (Thermal) from Radiative Heat Flux**
BRANZFIRE	192s	608s	320s	
FDS Device - 1	124s	675s	243s	> 1800s
FDS Device - 2	126s	682s	239s	> 1800s
FDS Device - 3	117s	660s	248s	> 1800s
FDS Device - 4	122s	648s	239s	> 1800s
FDS Device - 5	110s	675s	239s	> 1800s
FDS Device - 6	126s	648s	243s	> 1800s
FDS Device - 7	115s	696s	247s	> 1800s
FDS Device - 8	122s	691s	257s	> 1800s

Table 8-3: Results from FDS in NFPA5000 non-compliance buildings (Not Sprinkler Protected)

Fire Located in Storage Area (Not Sprinkler Protected)				
Device	**Visibility**	**FED (CO)**	**FED (Thermal) from Gauge Heat Flux**	**FED (Thermal) from Radiative Heat Flux**
BRANZFIRE	74s	262s	87s	
FDS Device - 1	74s	180s	92s	105s
FDS Device - 2	76s	177s	107s	132s
FDS Device - 3	78s	191s	90s	96s
FDS Device - 4	102s	200s	30s	31s
FDS Device - 5	98s	212s	33s	33s
FDS Device - 6	78s	180s	95s	103s
FDS Device - 7	79s	165s	102s	117s
FDS Device - 8	78s	176s	90s	100s
Fire Located in Drive Thru Area (Not Sprinkler Protected)				
Device	**Visibility**	**FED (CO)**	**FED (Thermal) from Gauge Heat Flux**	**FED (Thermal) from Radiative Heat Flux**
BRANZFIRE	96s	224s	96s	
FDS Device - 1	103s	230s	72s	113s
FDS Device - 2	103s	241s	70s	72s
FDS Device - 3	104s	241s	70s	73s
FDS Device - 4	111s	241s	35s	37s
FDS Device - 5	111s	252s	34s	35s
FDS Device - 6	99s	234s	74s	108s
FDS Device - 7	100s	235s	72s	73s
FDS Device - 8	100s	230s	72s	75s
Fire Located in Physiotherapy (Not Sprinkler Protected)				
Device	**Visibility**	**FED (CO)**	**FED (Thermal) from Gauge Heat Flux**	**FED (Thermal) from Radiative Heat Flux**
BRANZFIRE	143s	437s	277s	
FDS Device - 1	89s	436s	261s	303s
FDS Device - 2	60s	427s	209s	255s
FDS Device - 3	89s	444s	262s	324s
FDS Device - 4	89s	454s	259s	307s
FDS Device - 5	91s	454s	262s	312s
FDS Device - 6	87s	454s	267s	331s
FDS Device - 7	60s	430s	224s	260s
FDS Device - 8	89s	451s	267s	312s

Fire Located in Hostel (Not Sprinkler Protected)				
Device	**Visibility**	**FED (CO)**	**FED (Thermal) from Gauge Heat Flux**	**FED (Thermal) from Radiative Heat Flux**
BRANZFIRE	122s	419s	251s	
FDS Device - 1	70s	371s	215s	250s
FDS Device - 2	76s	323s	215s	250s
FDS Device - 3	76s	371s	215s	250s
FDS Device - 4	47s	534s	174s	209s
FDS Device - 5	47s	534s	143s	209s
FDS Device - 6	70s	371s	215s	250s
FDS Device - 7	76s	323s	215s	250s
FDS Device - 8	70s	371s	215s	250s
Fire Located in Communicating Space (Not Sprinkler Protected)				
Device	**Visibility**	**FED (CO)**	**FED (Thermal) from Gauge Heat Flux**	**FED (Thermal) from Radiative Heat Flux**
BRANZFIRE	431s	1700s	726s	
FDS Device - 1	241s	1042s	612s	775s
FDS Device - 2	262s	1062s	618s	779s
FDS Device - 3	241s	1062s	605s	756s
FDS Device - 4	258s	1062s	584s	725s
FDS Device - 5	262s	1062s	589s	725s
FDS Device - 6	235s	1042s	600s	731s
FDS Device - 7	258s	1062s	612s	724s
FDS Device - 8	248s	1042s	612s	775s
Fire Located in Anchor building – 3 (Not Sprinkler Protected)				
Device	**Visibility**	**FED (CO)**	**FED (Thermal) from Gauge Heat Flux**	**FED (Thermal) from Radiative Heat Flux**
BRANZFIRE	477s	1020s	554s	
FDS Device - 1	239s	834s	529s	621s
FDS Device - 2	260s	878s	491s	569s
FDS Device - 3	237s	939s	529s	621s
FDS Device - 4	218s	834s	529s	621s
FDS Device - 5	229s	899s	523s	621s
FDS Device - 6	218s	842s	513s	613s
FDS Device - 7	267s	890s	491s	592s
FDS Device - 8	227s	848s	529s	636s

8.5 RSET Calculations

The egress calculations were based on the results from chapters 4 to 7 except the activation time was determined from FDS. The activation time of sprinkler and the RSET are summarised in the Table 8-4 below. This result was used to compare the ASET results in the following section.

Table 8-4: RSET Results

Fire Location	Sprinkler Activation Time (s)		RSET (s)	
	BRANZFIRE	FDS	BRANZFIRE	FDS
Storage area	70	52	123	105
Drive thru area	72	53	152	133
Physiotherapy	153	148	264	259
Hostel	59	49	143	133
Communicating space	467	316	895	744
Restaurant	200	174	524	498
Anchor building – 3	244	264	538	558

8.6 ASET and RSET Analysis

All the NFPA5000 compliance case study buildings were protected with automatic sprinkler system and therefore the criterion for occupant tenability was based on FED for carbon monoxide. On the other hand, the criterion for occupant tenability was based on Visibility for all the NFPA5000 non-compliance case study buildings not provided with automatic sprinkler system. A summary of ASET and RSET for the NFPA5000 compliance and non-compliance buildings are summarised in Table 8-5 and Table 8-6 respectively.

Table 8-5: ASET and RSET for NFPA5000 compliance buildings (Sprinkler Protected)

Fire Located in Storage Area (Sprinkler Protected)				
Device	ASET	RSET	Margin	Scenario Result
BRANZFIRE	346s	123s	223s	Comply
FDS Device - 1	304s	105s	197s	Comply
FDS Device - 2	293s	105s	186s	Comply
FDS Device - 3	325s	105s	218s	Comply
FDS Device - 4	363s	105s	256s	Comply
FDS Device - 5	401s	105s	294s	Comply
FDS Device - 6	300s	105s	193s	Comply

FDS Device - 7	290s	105s	183s	Comply
FDS Device - 8	325s	105s	218s	Comply
Fire Located in Drive Thru Area (Sprinkler Protected)				
Device	**ASET**	**RSET**	**Margin**	**Scenario Result**
BRANZFIRE	290s	152s	138s	Comply
FDS Device - 1	464s	133s	331s	Comply
FDS Device - 2	436s	133s	303s	Comply
FDS Device - 3	446s	133s	313s	Comply
FDS Device - 4	473s	133s	340s	Comply
FDS Device - 5	446s	133s	313s	Comply
FDS Device - 6	413s	133s	280s	Comply
FDS Device - 7	450s	133s	317s	Comply
FDS Device - 8	450s	133s	317s	Comply
Fire Located in Physiotherapy (Sprinkler Protected)				
Device	**ASET**	**RSET**	**Margin**	**Scenario Result**
BRANZFIRE	1150s	264s	881s	Comply
FDS Device - 1	1073s	259s	814s	Comply
FDS Device - 2	1026s	259s	767s	Comply
FDS Device - 3	1026s	259s	767s	Comply
FDS Device - 4	1026s	259s	767s	Comply
FDS Device - 5	1026s	259s	767s	Comply
FDS Device - 6	1061s	259s	802s	Comply
FDS Device - 7	1090s	259s	831s	Comply
FDS Device - 8	1050s	259s	791s	Comply
Fire Located in Hostel (Sprinkler Protected)				
Device	**ASET**	**RSET**	**Margin**	**Scenario Result**
BRANZFIRE	916s	143s	773s	Comply
FDS Device - 1	1067s	133s	934s	Comply
FDS Device - 2	1056s	133s	923s	Comply
FDS Device - 3	1056s	133s	923s	Comply
FDS Device - 4	1056s	133s	923s	Comply
FDS Device - 5	1032s	133s	899s	Comply
FDS Device - 6	1056s	133s	923s	Comply
FDS Device - 7	1090s	133s	957s	Comply
FDS Device - 8	1056s	133s	923s	Comply
Fire Located in Communicating Space (Sprinkler Protected)				
Device	**ASET**	**RSET**	**Margin**	**Scenario Result**
BRANZFIRE	2250s	895s	1360s	Comply
FDS Device - 1	1633s	744s	889s	Comply
FDS Device - 2	1633s	744s	889s	Comply

FDS Device - 3	1586s	744s	842s	Comply
FDS Device - 4	1702s	744s	958s	Comply
FDS Device - 5	1596s	744s	852s	Comply
FDS Device - 6	1621s	744s	877s	Comply
FDS Device - 7	1679s	744s	935s	Comply
FDS Device - 8	1633s	744s	889s	Comply
Fire Located in Restaurant (Sprinkler Protected)				
Device	**ASET**	**RSET**	**Margin**	**Scenario Result**
BRANZFIRE	608s	524s	84s	Comply
FDS Device - 1	675s	498s	191s	Comply
FDS Device - 2	682s	498s	188s	Comply
FDS Device - 3	660s	498s	166s	Comply
FDS Device - 4	648s	498s	154s	Comply
FDS Device - 5	675s	498s	181s	Comply
FDS Device - 6	648s	498s	154s	Comply
FDS Device - 7	696s	498s	202s	Comply
FDS Device - 8	691s	498s	197s	Comply

Table 8-6: ASET and RSET for NFPA5000 non-compliance buildings (Not Sprinkler Protected)

Fire Located in Storage Area (Not Sprinkler Protected)				
Device	**ASET**	**RSET**	**Margin**	**Scenario Result**
BRANZFIRE	80s	123s	-43s	Not Comply
FDS Device - 1	74s	105s	-31s	Not Comply
FDS Device - 2	76s	105s	-29s	Not Comply
FDS Device - 3	78s	105s	-27s	Not Comply
FDS Device - 4	102s	105s	-3s	Not Comply
FDS Device - 5	98s	105s	-7s	Not Comply
FDS Device - 6	78s	105s	-27s	Not Comply
FDS Device - 7	79s	105s	-26s	Not Comply
FDS Device - 8	78s	105s	-27s	Not Comply
Fire Located in Drive Thru Area (Not Sprinkler Protected)				
Device	**ASET**	**RSET**	**Margin**	**Scenario Result**
BRANZFIRE	96s	152s	-56s	Not Comply
FDS Device - 1	103s	133s	-30s	Not Comply
FDS Device - 2	103s	133s	-30s	Not Comply
FDS Device - 3	104s	133s	-29s	Not Comply
FDS Device - 4	111s	133s	-22s	Not Comply
FDS Device - 5	111s	133s	-22s	Not Comply

FDS Device - 6	99s	133s	-34s	Not Comply
FDS Device - 7	100s	133s	-33s	Not Comply
FDS Device - 8	100s	133s	-33s	Not Comply
Fire Located in Physiotherapy (Not Sprinkler Protected)				
Device	**ASET**	**RSET**	**Margin**	**Scenario Result**
BRANZFIRE	143s	264s	-121s	Not Comply
FDS Device - 1	89s	306s	-217s	Not Comply
FDS Device - 2	60s	306s	-246s	Not Comply
FDS Device - 3	89s	306s	-217s	Not Comply
FDS Device - 4	89s	306s	-217s	Not Comply
FDS Device - 5	91s	306s	-215s	Not Comply
FDS Device - 6	87s	306s	-219s	Not Comply
FDS Device - 7	60s	306s	-246s	Not Comply
FDS Device - 8	89s	306s	-217s	Not Comply
Fire Located in Hostel (Not Sprinkler Protected)				
Device	**ASET**	**RSET**	**Margin**	**Scenario Result**
BRANZFIRE	122s	143s	-21s	Not Comply
FDS Device - 1	70s	133s	-63s	Not Comply
FDS Device - 2	76s	133s	-57s	Not Comply
FDS Device - 3	76s	133s	-57s	Not Comply
FDS Device - 4	47s	133s	-86s	Not Comply
FDS Device - 5	47s	133s	-86s	Not Comply
FDS Device - 6	70s	133s	-63s	Not Comply
FDS Device - 7	76s	133s	-57s	Not Comply
FDS Device - 8	70s	133s	-63s	Not Comply
Fire Located in Communicating Space (Not Sprinkler Protected)				
Device	**ASET**	**RSET**	**Margin**	**Scenario Result**
BRANZFIRE	431s	895s	-464s	Not Comply
FDS Device - 1	241s	744s	-503s	Not Comply
FDS Device - 2	262s	744s	-482s	Not Comply
FDS Device - 3	241s	744s	-503s	Not Comply
FDS Device - 4	258s	744s	-486s	Not Comply
FDS Device - 5	262s	744s	-482s	Not Comply
FDS Device - 6	235s	744s	-509s	Not Comply
FDS Device - 7	258s	744s	-486s	Not Comply
FDS Device - 8	248s	744s	-744s	Not Comply
Fire Located in Anchor Building – 3 (Not Sprinkler Protected)				
Device	**ASET**	**RSET**	**Margin**	**Scenario Result**
BRANZFIRE	477s	538s	-61s	Not Comply
FDS Device - 1	239s	570s	-319s	Not Comply

FDS Device - 2	260s	570s	-298s	Not Comply
FDS Device - 3	237s	570s	-321s	Not Comply
FDS Device - 4	218s	570s	-340s	Not Comply
FDS Device - 5	229s	570s	-329s	Not Comply
FDS Device - 6	218s	570s	-340s	Not Comply
FDS Device - 7	267s	570s	-291s	Not Comply
FDS Device - 8	227s	570s	-331s	Not Comply

8.7 Conclusion of DFS1 using FDS

Three case study buildings designed in accordance with NFPA5000 was modelled using FDS. The results show that all occupants in the buildings had sufficient time to make their escape before the untenable condition occurred and the buildings achieved DFS1. In the analyses where the buildings were not protected with automatic sprinkler system, these NFPA5000 non-compliance buildings did not comply with DFS1. The FDS results were compared with the BRANZFIRE results and they were agreed with each other.

9 Conclusions

Ten design fire scenarios have been included in the framework to ensure that designers have considered the fire scenarios and that buildings in similar use would provide consistent levels of safety for performance based fire design. Three case study buildings designed in accordance with and substantially altered from the prescriptive requirements of NFPA5000 were tested against the New Zealand Performance Based Design Fire Framework. The conclusions from the research are presented below:

9.1 NFPA5000 Compliance Case Study Buildings

Three case study buildings provided with fire protection features in accordance with NFPA5000 prescriptive requirements were investigated:

- To determine the available safety egress time, the framework listed clearly the acceptance criteria, provided easy to follow fire modelling rules for computer fire modelling, and specified the characteristic of design fires based on the building use. The framework also detailed the method and provided references on occupant evacuation modelling in order to determine the RSET. Design Fire Scenario One (Challenging Fire) results from BRANZFIRE were consistent with the results from FDS. The framework provided a robust and consistent method for performance based fire design and the guidance provided in the framework gave a clear methodology to determine the ASET and the RSET.
- The north external wall of the retail warehouse did not require to be fire rated in accordance with NFPA5000 (detailed in Appendix A section A1.5.2). The building failed to comply with Design Fire Scenario Six (Spread to Other Property) because the external wall was only allowed 48% unprotected area in accordance the framework, as discussed in section 4.8. The relevant clause and tables from NFPA5000 and C/AS1 were attached in Appendix E. The framework provided a more restrictive requirement than the prescriptive requirement in NFPA5000 in relation to external walls fire resistance.

- Case Study Building One (Retail Warehouse) failed to comply with Design Fire Scenario Nine (Fire Service Operations). The mezzanine floor which does not require any fire rating in NFPA5000 is required to be fire rated in order to comply with the framework. The framework provided a more restrictive requirement than that in NFPA5000 in relation to mezzanine floor fire resistance.

9.2 NFPA5000 Non-Compliance Case Study Buildings

Three case study buildings provided with fire protection features substantially altered from NFPA5000 prescriptive requirements were investigated. Findings from each case study building were:

- In section 7.2 (Ineffective Sprinkler System), automatic sprinkler system in the buildings was assumed to be non-operational, all the buildings did not comply with Design Fire Scenario One (Challenging Fire). The framework was able to test buildings to ensure they provided adequate fire safety features to maintain minimum performance-based fire design requirements. The minimum performance-based fire design requirement in the framework was not substandard in comparison with the prescriptive requirement in NFPA5000 in relation to automatic suppression system.
- In section 7.3 (Ineffective Smoke Detection System), smoke detection system in the hostel (hospital) was assumed to be non-operational. The non-compliance building complied with Design Fire Scenario One (Challenging Fire). However, Design Fire Scenario Five (Smouldering Fire) required an automatic smoke detection and alarm system to be provided in a sleeping area (hostel). The framework did not provide a less rigorous requirement than that in NFPA5000 in relation to sleeping occupants.
- In section 7.4 (Ineffective Interior Fire/Smoke Separations), self-closing devices on fire doors and internal fire/smoke separations were deemed ineffective. The non-compliance hospital and shopping mall complied with Design Fire Scenario One (Challenging Fire). The framework allowed buildings to be designed without any self-closing devices and internal fire/smoke separations which were required in accordance with NFPA5000 prescriptive requirements. The framework provided a less

rigorous requirement than that in NFPA5000 in relation to fire compartmentation.

- In section 7.5 (Reduced Exit(s)), the required exits in the room of fire origin were significantly reduced. The total exits in the non-compliance retail area and anchor building – 3 were reduced from three exits to two exits. Whist communicating space was reduced from seven exits to two exits. The buildings complied with Design Fire Scenario One (Challenging Fire) and Design Fire Scenario Two (Blocked Exit). The framework allowed the buildings to be designed with lesser egress capacity than NFPA5000. It provided a less rigorous requirement in comparison with the NFPA5000 in relation to means of egress.
- Each storage area, drive thru area, mezzanine and hostel was required at least two exits in accordance with NFPA5000. In section 7.5 (Reduced Exit(s)), the total exit in each of the above areas was reduced to single exit. The buildings complied with Design Fire Scenario One (Challenging Fire). Each area served less than 50 people and therefore Design Fire Scenario Two (Blocked Exit) did not apply. The framework allowed the buildings to be designed with lesser egress capacity than NFPA5000. The framework provided a less rigorous requirement in comparison with the NFPA5000 in relation to means of egress.

10 Recommendations

Three case study buildings designed in accordance with NFPA5000 prescriptive requirements as well as the buildings designed to be altered from NFPA5000 prescriptive requirements were investigated against the framework. The framework is able to challenge the buildings with lesser fire protection features as the margins between ASET and RSET are reduced significantly. As discussed in chapter 9.1, the framework provided a more restrictive performance-based requirement than the prescriptive requirement in NFPA5000, including fire resistant rating of external wall and mezzanine floor. On the other hand the framework provided a less rigorous fire compartmentation and egress capacity requirements than NFPA5000 prescriptive requirement (discussed in chapter 9.2). As the objective of this research is to provide feedback and recommendations to the DBH, some potential changes and future works to the framework should be considered. It is recommended that:

1. the expected methodology for Design Fire Scenario Six (Spread to Other Property) (DFS6) is recommended to incorporate the fire resistance rating of exterior walls requirements in Section 7.3 of NFPA5000 and therefore the performance measures of DFS6 will not only based on the bounding fire spread requirements in C/AS1 but also based on the fire resistance rating of exterior walls requirements in NFPA5000. As a result, the framework would not provide a more restrictive performance-based requirement than the prescriptive requirement in NFPA5000;

2. fire resistance requirement for a mezzanine floor in the firefighter tenability criteria be removed where buildings have sprinkler system throughout. The likelihood of a large fire developing in the building is significantly reduced due to the provision of sprinkler protection throughout the building. The fire brigade would be expected to arrive and set up before any excessive deflections or localised damage to the structure occurs;

3. further scenarios for performance measures are required to be developed for fire compartmentation (self-closing devices and internal fire/smoke separations). It is to limit the spread of fire/smoke;

4. further scenarios for performance measures are required to be developed for egress capacity. It is to ensure occupants have sufficient exits to enable safe egress in an event of a fire.

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Appendix A: NFPA5000 Prescriptive Design

Appendix A1: Retail Warehouse

A1.1 Introduction

The purpose of this appendix is to identify minimum requirements for the retail warehouse as mandated by NFPA 5000 Building Construction and Safety Code (the Code) and provides design suggestions to areas where the building cannot meet the provisions of the Code. The report summarises and identifies the minimum fire protection and life safety requirements contained in the code and standards applicable to the building. This report refers to ***Paragraph, Section*** and ***Table*** with the same numbering as the Code unless stated otherwise.

A1.2 Building Description

The building is a single storey retail warehouse with a mezzanine floor located at the west side of the warehouse. The ground floor of the warehouse contains retail area, drive thru area, storage room and toilet facilities. The mezzanine will be used for offices and staff rooms. The retail area is the main area and located at the centre of the warehouse. The drive thru area and storage room are on the east and west side of the building respectively. The building will be one firecell and there will be considerable time periods that the building is unoccupied.

The building is 40 m wide, 60 m long and 8 m height. It contains a store room, retail area, small office, drive thru and intermediate floor. The building layout is provided in Figure A1-1.

A1.2.1 Occupancy Classifications, Hazard Contents and Occupant Load

Section 6.1 classifies the overall building occupancy as a Mercantile Occupancy. Retail and Drive Thru area is classified as Mercantile Occupancy, Intermediate floor and small office is classified as Business Occupancy and Stock room is classified as Storage Occupancy as per ***Paragraph 6.1.10***, ***Paragraph 6.1.10*** and ***Paragraph 6.1.10***. However, ***Paragraph 6.2.1.3(1)*** states minor office space and small storage area can be incidental to occupancy. Therefore, the building is classified as Mercantile Occupancy and the overall building occupancy do not considered as multiple occupancies. Furthermore, the building is subclassified as Class B as per ***Paragraph 27.1.3.2.1(2)***.

The classification of Hazard of Contents for the building has been taken from ***Section 6.3.2***.

Occupant load factors are expressed in terms of square meters per person. The Code uses occupant load factors to determine the allowable number of occupants in a given area and also allows the occupant load to be increased above the calculated number provided the other egress provisions are met and the occupant load does not exceed 0.46 m^2/person. The occupant load is calculated from relevant occupant load factors taken from ***Table 11.3.1.2***. The occupancy classification, fire hazard classification, area and occupant load are detailed in Table A1-1. The overall activity, occupancy type and occupant load are included in Figure A1-1 and Figure A1-2.

Table A1-1: Occupancy Classifications, Hazard Contents and Occupant Load

Area	Occupancy	Fire Hazard	Occupant Load Factor (m^2 per person)	Gross Area (m^2)	Occupant Load (persons)
Retail	Mercantile Class B	Ordinary	2.8	1680	600
Small Office	Mercantile Class B	Ordinary	9.3	32	4
Drive Thru	Mercantile Class B	Ordinary	27.9	411	15
Intermediate Floor	Mercantile Class B	Ordinary	9.3	269	29
Stock Room	Mercantile Class B	Ordinary	27.9	326	12
			Total	**2718**	**660**

A1.2.2 Mezzanines

Paragraph 8.13.1.1 states mezzanine is not counted as a story in a building for the purpose of determining the allowable number of stories in a building. The use of the one-third area rule specified in ***Section 8.13.2*** is for determining whether a level is a mezzanine. The intermediate floor complies with the requirement set forth in ***Section 8.13.2*** as the aggregate area of the intermediate floor not exceeds one-third the open area of the building. The intermediate floor is a mezzanine.

The mezzanine is enclosed and required to provide at least two means of egress providing at least one of the means of egress accesses directly from the enclosed area to an exit at the mezzanine level as per ***Paragraph 8.13.3.2***. The allowable common path of travel is exceeded in the mezzanine and it is required to provide a second exit access. Inside open stairway is permitted to serve as a component of the required means of egress system for this building as per ***Paragraph 27.2.1.2.***

The mezzanine provides two means of egress. The occupants can travel across the mezzanine, down the open stairway to the room below, and travel across the floor of that room to reach an exit. The occupants can also access from the mezzanine directly into an enclosed stairway that discharges to the outside.

A1.2.3 High Rise Building

The floor height measured from the lowest level of fire department vehicle access to the highest floor of an occupied story is not greater than 23 m. The building is not considered as a high rise building as defined in ***Paragraph 3.3.64.10***.

A1.3 Construction

A1.3.1 Type of Construction

The external constructions are concrete walls and the internal constructions are gypsum boards. Buildings and structures shall be classified according to their type of construction as per ***Paragraph 7.2.1.1***. NFPA 220, Standard on Types of Building Construction, shall be used to determine the requirements for the construction classification. Concrete wall and gypsum are classified as Type II construction because they are non-combustible or limited combustible material as per ***Paragraph 7.2.3.1***. The construction of the building is Type II construction.

The north wall of the building is 7m from the property line, 22 m to the East, 30 m to the South and 0.1 m to the West. North, east and south exterior walls are not required to have a fire resistance rating as per ***Table 7.3.2.1***. For a separation distance between the building and the property line of less than or equal to 3 m, exterior walls are required to have a fire resistance rating.

A1.3.2 Allowable Building Height and Area

The code regulates the height and area of buildings based on occupancy of the building and construction type. ***Table 7.4.1*** limits the area of the Mercantile Occupancy of Type II (000) sprinklered buildings to 1162 m^2 and five stories.

An automatic sprinkler system is installed throughout the building, the allowable building area per story specified in ***Table 7.4.1*** shall be permitted to be increased at least four times (I_S = 300 and assumed I_f = 0) as per ***Paragraph 7.6.2*** and ***Paragraph 7.6.2.2(2)***. The allowable building area per story shall not exceed 4648 m^2 for Type II (000), maximum building height shall not exceed 22.8 m and the allowable number of stories shall not exceed five as per ***Table 7.4.1***.

The building is classified as a one story building and has 2718 m^2 floor area. The building achieved the allowable height and area requirements. The allowable height and area are summarised in Table A1-2.

Table A1-2: Allowable Height and Area

	Actual	Allowable (*Table 7.4.1*)	Increase for Sprinklers
Type of Construction: Type II (000)			
Building Height (m)	0	16.7	22.8
Building Height (Stories)	1	4	5
Building Area (m^2)	2718	1162	4848

A1.4 Life Safety System Requirements

A1.4.1 Automatic Sprinkler System

A combination of factors including occupancy, building area, construction type, building height, location relative to exit discharge and occupant load trigger sprinkler protection for buildings. Several exceptions are allowed but none of the exceptions are relevant to the building.

The code mandates Mercantile Occupancies to be protected by an approved, supervised automatic sprinkler system in accordance with NFPA13 and ***Paragraph 55.3.2*** if gross area exceeds 1115 m^2. ***Paragraph 27.3.5.1(2)*** requires automatic sprinkler system protection for the building.

A1.5 Fire Protection Requirements

A1.5.1 Internal Spread of Fire and Smoke

A1.5.1.1 Vertical Openings

Section 8.12 states that enclosures connecting three stories or less shall provide at least one hour fire barrier but not less than the required fire resistance rating of the floor penetrated, and construct as a smoke barrier to restrict the passage of smoke.

A1.5.1.2 Vertical Exit Enclosures

Vertical exit enclosures such as interior exit stairways shall be enclosed with fire barriers. Exit enclosures shall have a fire resistance rating not less than one hour where connecting less than four stories and not less than two hour where connecting four stories or more as per ***Section 11.1.3***.

Referring to section 2.2 of this appendix, occupants are able to travel from the enclosed area at the mezzanine level to an enclosed stairway and access directly to outside. The enclosed stairway is required to achieve at least one hour fire resistance rating as per ***Paragraph 11.1.3.2.1.1***. The enclosed stairway acts as a vertical shaft, 1 hour fire resistance rating is required for walls and 1 hour fire resistance rating is required for fire door assemblies as per ***Table 8.7.2***.

However, unprotected vertical openings are permitted between the ground floor and the mezzanine as per **Paragraph 27.3.1**. Smoke barriers and fire resistance rating for the enclosed stairway that provides direct access to an exit at the mezzanine level are not required.

An exit enclosure shall provide a continuous protected path of travel to an exit discharge as per ***Paragraph 11.1.3.2.2***.

A1.5.1.3 Corridors

Although ***Paragraph 11.1.3.1*** states that corridor used as exit access and serving more than 30 occupants are required to be separated from other parts of the building by walls having at least one hour fire resistance rating, but it is not required any fire resistance rating because the building is protected by an approved automatic sprinkler system as per ***Paragraph 27.3.6.1***.

A1.5.1.4 Miscellaneous Requirements

Mezzanine floor is Type II (000) construction and it is not required to have fire resistance rating as per ***Paragraph 7.2.3.2.4***.

The storage area in the building does not require any special hazard protection in ***Section 8.15*** because an automatic sprinkler system is installed throughout the building as per

Paragraph 27.3.2.1.2.

A1.5.2 External Spread of Fire and Smoke

The minimum fire resistance ratings for Type II (000) construction are given in ***Table 7.2.1.1*** and ***Table 7.3.2.1***, whichever is greater as per ***Paragraph 7.3.2.1***.

Paragraph 7.3.9 specified the requirements for vertical separation of exterior openings. The building does not require vertical separation of exterior openings as per ***Paragraph 37.1.4.1***.

Allowable area of unprotected openings for the North, East and South walls have not been exceeded that permitted by ***Table 7.3.5(b)*** because they are not required to have a fire resistance rating as determined by ***Table 7.3.2.1*** as per ***Paragraph 7.3.5***. The West wall needs to be fire rated for two hours and there is no allowable area of unprotected openings to be tested by ***Table 7.3.5(b)***. ***Paragraph 7.3.5*** is complied. The applicable data is summarised in Table A1-3 and Table A1-4. The distance to the relevant boundary is shown in Figure A1-1 and the overall exterior passive fire protection requirements are given in Figure A1-3.

Table A1-3: Fire Resistance Rating Requirements for Exterior Walls on Fire Separation Distance

Location	Enclosing rectangle H x W (m)	Distance to the relevant Boundary (m)	Fire Resistance rating (hr)	Percentage of Unprotected Areas	
				Allowed[1] (%)	Actual (%)
North Wall	63 x 7.5	7	0	100	100 - OK
East Wall	39.1 x 7.5	22	0	100	100 - OK
South Wall	63 x 7.5	30	0	100	100 - OK
West Wall	39.1 x 7.5	0.1	2	0	0 - OK

Note 1: The allowable unprotected areas of the external walls have been addressed using ***Table 7.3.5(b)*** and are permitted to be doubled as per ***Paragraph 7.3.5.5.1***.

Table A1-4: Fire Resistance Rating Requirements for Building Elements

Building Element	Fire Separation Distance (m)	Required Rating (Hours)
Bearing Walls		
Exterior		
North	7	0
East	22	0
South	30	0
West	0.1	2
Interior	-	0
Non Bearing Walls and Partitions		
Exterior		
North	7	0
East	22	0
South	30	0
West	0.1	2
Interior	-	0
Floor Construction	-	0
Roof construction	-	0
Columns, Beans, Girders, Trusses and Arches	-	0
Occupant Separation	-	0
Corridor Separation	-	0
Fire Wall Separation	-	0
Vertical Separation of exterior openings	-	0
Smoke Barrier Separation	-	0
Tenant Separation	-	0
Shafts for exit	-	0
Shafts for other	-	0

A1.6 Means of Escape

A1.6.1 Exits

The minimum number of exits is generally based on ***Section 11.4.1***. All rooms and spaces within each story shall be provided with and have access to the minimum number of exits as follows (refer to Figure A1-3 and Figure A1-4 for the location of exits):

- Under 500 occupants requires a minimum of two exits
- 500 occupants to 1000 occupants requires a minimum three exits

- Over 1000 occupants requires a minimum four exits

As per ***Section 11.4***, two is the minimum acceptable number of escape routes for the Store room, Mezzanine, Drive thru, and small office on ground floor; three is the minimum acceptable number of escape routes for the Retail area. The Drive thru complies the requirement. Single means of escape is allowed as per the requirements of ***Paragraph 27.2.4*** but none of the area in the building is relevant to the requirement.

A1.6.2 Length of Escape RoutesA1.6.2.1 Dead-ends Corridors

Paragraph 27.2.5.2 states that dead-end corridors shall not exceed 15 m for sprinklered building. Each area in the building provides at least two means of egress. Neither of them is associated with corridors and no other dead ends existed.

A1.6.2.2 Common Path of Travel

Paragraph 27.2.5.3 limits the common path of travel to 15 m or less for sprinklered building. Common path of travel is the portion of the means of egress that must be traversed until such a point that at least two independent means of egress to at least two exits are available. The common path of travel from the Small Office on ground floor leading to the Drive Thru area is 7 m, and travel out of the office at the mezzanine level is 10 m. The building complied with the common path of travel provisions.

A1.6.2.3 Travel Distance

Paragraph 27.2.6 requires the maximum travel distance measured from the most remote place in the building to an exit not exceed 76 m for sprinklered building. The travel distance in the building is less than or equal to 76 m.

If there are two exits, the maximum travel distance is measured from the most remote point in a room to the nearest exit.

The maximum escape route lengths are as shown below in Table A1-5. Travel direction and travel distance are detailed in Figure A1-3 and Figure A1-4.

Table A1-5: Length of Escape Routes

Area	Occupancy	Dead End Corridor (m)		Common Path (m)		Travel Distance (m)	
		Allowed[1]	Actual	Allowed[1]	Actual	Allowed[1]	Actual[2]
Retail	Mercantile	15	0	30	0	76	33
Office	Mercantile	15	0	30	7	76	22
Drive Thru	Mercantile	15	0	30	0	76	24
Mezzanine	Mercantile	15	0	30	10	76	42
Stock room	Mercantile	15	0	30	0	76	27

Note 1: Approved and supervised automatic sprinkler system is installed throughout the building in accordance with NFPA 13 and ***Paragraph 55.3.2***

Note 2: On entering a protected stairs or exit the occupants are considered to have ended their travel distance

A1.6.3 Arrangement of Means of Egress

As per ***Paragraph 11.5.1.2***, corridor shall provide exit access without passing through any intervening rooms. The building does not contain any corridor and is complied with the Paragraph.

Access to an exit shall not pass through kitchens; restroom; closets; bedrooms or similar spaces; or other rooms or spaces subject to locking as per ***Paragraph 11.5.2***, unless the following condition exists:

- Storerooms in Class A and Class B Mercantile Occupancies that are protected throughout by an approved, supervised automatic sprinkler system as per ***Paragraph 27.2.5.8***

The building is equipped throughout with an automatic sprinkler system. ***Section 11.5.1.4*** requires the exits to be separated by at least one-third of the length of the maximum overall diagonal dimension of the building area served, measured in a straight line between the nearest edge of the exits.

The diagonal of the Retail area served is 58.5 m. ***Section 11.5.1.4*** requires a separation of

19.5 m. Two exits on the North wall are 31.5 m apart. The building meets the requirement.

A1.6.4 Exit Discharge Requirements

The building has provided more than 50 percent of the required number of exits and more than 50 percent of the required egress capacity directly to outside to meet the 50 percent exit discharge requirement as specified in ***Section 11.7*** and ***Paragraph 27.2.7.2***.

A1.6.5 Capacity of Means of Escape

A1.6.5.1 Exit Access Corridor

The building does not contain any exit access corridor

A1.6.5.2 Doors

As per ***Section 11.1.5*** and ***Section 11.2.1.2.3***, the minimum 2.03 m height and 0.81 m clear width door openings in means of egress have been achieved. All doors provided a clear opening of at least 0.81 m and shall not obstruct the required escape route width, unless one of the following conditions exists:

- For the total cumulative occupant load assigned to a particular stairway more than or equal to 2000 people, such stairway is required to be a minimum 1.42 m width in accordance with ***Paragraph 11.2.2.2.1.1 (B)*** and such door is required to be a minimum 0.94 m (two-thirds of the required width of the stairway) clear width as per ***Paragraph 11.2.1.2.3.2 (8)***. The building does not contain more than 2000 people and not require to meet the provision of ***Paragraph 11.2.1.2.3.2 (8)***.

As per ***Section 11.2.1.4.3***, all doors leaves in a means of egress have left more than one-half of the required width of a corridor when they swing and swung in the direction of egress travel. All doors have not projected more than 0.18 m into the required with of corridor or landing when fully open. All doors leaves open directly onto a stair with a landing.

A1.6.5.3 Stairway at mezzanine level

The elevation of the floor surfaces on both sides of a door and thresholds at door openings are not exceed 13 mm. The stairway has landings at door openings and has maintained the same width along the direction of egress travel.

The minimum stairway width is 0.915 m because it serves an occupant load less than 50 people as per ***Paragraph 11.2.2.2.1.1 (A)***. The landings and the width of the stairway are 1.2 m in the direction of travel. They are not less than the width of the widest door leaf and are not less than the width of the stair. The stairway satisfies the requirements in ***Section 11.2.1.3***, ***Section 11.2.1.4.3*** and ***Section 11.2.2.3.2***.

A1.6.5.4 Stairs

Dimensional criteria for stairs have been addressed using ***Table 11.2.2.2.1***. The minimum 0.915 m clear width, maximum 0.18 m and minimum 0.10 m height of risers, minimum 0.28 m tread depth, minimum 2.03 m headroom and maximum 3.66 m height between landings of the stairs have been achieved. Note that a stair is used to meet the requirement of changes in level in means of egress in ***Section 11.1.7***, the tread depth of the stair shall be not less than 0.33 m as per ***Paragraph 11.1.7.2.2***.

The stair width is 1.2 m and the height between landings is 3.5 m. The tread depth and the riser height of the stair are 0.33 m and 0.175 m respectively. All stairs shall not obstruct the required escape route width.

A1.6.5.5 Width of Egress Routes

Egress capacity factors are related to the minimum clear width required for exits to ensure occupants can safely egress the building through the exits. Egress capacity factors are expressed in millimeter per person. The egress capacity factors for level egress components and stairways are different. Clear widths are determined from egress capacity factors and the maximum capacity for that particular egress element. The occupant load factor is based on ***Table 11.3.1.2*** and ***Table 11.3.3.1*** contains the capacity factors for egress elements. The capacity of means of escape is sufficient for the occupant load.

For an area has more than one means of egress, the reminding egress capacity has at least 50 percent of the required egress capacity if one of the egress routes is blocked as per ***Paragraph 11.3.1.1.2***. All the staircases in the building serve more than one story and each staircase capacity is based on the portion of the story’s occupant load assigned to that stair as per ***Paragraph 11.3.1.4***. The egress capacity from the mezzanine passes through the Retail Area is included to the required egress capacity of the Retail Area as per ***Paragraph 11.3.1.6***.The capacity of the means of escape is summarised in Table A1-6.

Table A1-6: Capacity of Means of Escape

Activity	Occupant Load for egress	Egress width per Occupant		Required Exit Width (m)		Actual Exit Width (m)	
		Stair	Level	Stair	Level	Stair	Level
Retail	615	0.0076	0.005	4.7	3.1	-	3.1
Small Office	4	0.0076	0.005	0.1	0.02	-	0.81
Drive Thru	15	0.0076	0.005	0.2	0.075	-	1.62
Intermediate Floor	15	0.0076	0.005	0.2	0.075	0.81	1.62
Stock Room	12	0.0076	0.005	0.1	0.06	-	1.62

NOTES:

1. The aggregate width of aisles shall not be less than 0.915 m as per ***Section 27.2.5.4***
2. The one-half of the required egress width requirements at the customer entrance does no apply to this building because the building is a bulk merchandising retail building
3. Checkout stands shall provide at least one-half of the required exits (≥ 0.5 m)
4. Carts and Buggies shall meet the requirements specified in ***Paragraph 27.2.5.7***
5. Exit access through storerooms is allowed as per ***Paragraph 27.2.5.8*** provided that the conditions in the paragraph are met

A1.6.6 Accessible Means of Egress

As per ***Paragraph 11.5.4.1***, the building requires not less than two accessible means of egress. The small office is permitted to have a single accessible means of egress because it is permitted to have a single exit as per ***Paragraph 11.5.4.1.2*** and ***Paragraph 27.2.4(4)***. According to the provision of ***Paragraph 27.2.2.12.2***, the building is exempt from having to provide the two accessible rooms or spaces separated from each other by smoke resisting partitions. The building is protected with automatic sprinkler system and each space (except the small office) provides at least two means of egress routes to create the equivalent of two accessible means of egress.

A1.6.7 Door Swing and Self-closing Devices

Stair enclosure and horizontal exit are normally not secured in the open position and equipped with self-closing or automatic closing device as per ***Paragraph 11.2.1.8***. The criteria for automatic closing are listed in ***Paragraph 11.2.1.8.2***.

Fire doors shall comply with the requirements of ***Section 8.7*** and shall be self-closing or automatic-closing as per ***Section 8.7.3***.

Doors in the required means of egress are required to be open in the direction of egress travel if there are more than 50 occupants using the door or if the door is used in an exit enclosure.

A1.7 Interior Finish

Interior wall and ceiling finish material can be Class A or Class B or Class C because the building is sprinkler protected. Interior floor finish in all areas can be Class I or Class II or no critical radiant flux rating requirement (no classification required) because the building is sprinkler protected as per ***Section 16.3.3***, ***27.3.3***, ***30.8.3.3*** and ***10.7***. Detailed interior finish requirements are listed in Section 7.1 and 7.2.

A1.7.1 Interior Wall and Ceiling Finish

For the thickness of materials applied directly to the surface of walls and ceilings is less than 0.90 mm, the materials shall not be considered interior finish and shall be exempt from tests simulating actual installation if they are classified as Class A interior wall or ceiling finish.

Interior wall or ceiling finish shall be classified to be Class A, Class B or Class C based on test results from ASTM E 84, Standard Test Method of Surface Burning Characteristics of Building Materials, or UL 723, Standard for Test of Surface Burning Characteristics of Building Materials, or except as follows:

- Exposed portions of structural members is Type IV (2HH) construction
- Interior wall and ceiling finish tested in accordance with NFPA 286, Standard Methods of Fire Tests for Evaluating Contribution of Wall and Ceiling Interior Finish to Room Fire Growth, and are complied with the criteria of ***Paragraph 10.3.6.2***, are classified as Class A in accordance with ASTM E 84 or UL 723

Interior wall and ceiling finishes for the building must be grouped in classes as shown in Table A1-7. Specific materials, trim and incidental finish shall satisfy the requirements in ***Section 10.4*** and ***Section 10.5***.

Table A1-7: Interior Wall and Ceiling Finishes Classification

Classification	Flame Spread Index (FSI)	Smoke Developed Index (SDI)
Class A	0 – 25	0 – 450
Class B	26 – 75	0 – 450
Class C	76 - 200	0 – 450

NOTES:

1. If the use of Class C interior wall and ceiling finish is required, Class A or Class B shall be permitted. If class B interior wall and ceiling finish is required, Class A shall be permitted, as per ***Paragraph 10.3.5***.
2. Interior wall and ceiling finish tested in accordance with NFPA 265, Standard Methods of Fire Tests for Evaluating Room Fire Growth Contribution of Textile Coverings on Full Height Panels and Walls, shall comply with the criteria of ***Paragraph 10.3.6.1***.
3. If an approved automatic sprinkler system is installed, Class C interior wall and ceiling finish materials shall be permitted in any location where Class B is required, and Class B interior wall and ceiling finish materials shall be permitted in any location where Class A is required, as per ***Paragraph 10.7.1***.

A1.7.2 Interior Floor Finish

Interior floor finish such as carpet and carpetlike interior floor finishes shall comply with ASTM D 2859, Standard Test Method for Ignition Characteristics of Finished Textile Floor Covering Materials.

Interior floor finishes shall be classified to be Class I or Class II based on test results from NFPA 253, Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source, or ASTM E 648, Standard Test Method for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source. Interior floor finishes for the building must be grouped in classes as shown in Table A1-8.

Table A1-8: Interior floor Finishes Classification

Classification	Critical Radiant Flux
Class I	≥ 0.45 W/cm^2
Class II	≥ 0.22 W/cm^2 and < 0.45 W/cm^2

NOTES:

1 Floor coverings, other than carpet, that are judged to represent an unusual hazard shall have a minimum critical radiant flux of 0.1 W/cm^2, as per ***Paragraph 10.6.2***.

2 If an approved automatic sprinkler system is installed, Class II interior floor finish materials shall be permitted in any location where Class I is required; and where Class II is required, no critical radiant flux rating shall be required, as per ***Paragraph 10.7.2***.

A1.8 Fire Fighting

A fire department access to the building is to meet the requirement of ***Section 7.1.5.2***. The vehicular access shall not be more than 15 m away from an exterior door that provides access to the building and that can be opened from outside as per ***Paragraph 7.1.5.2.2.1*** and an unavailable access road around the exterior of the building shall not be over 137 m as per ***Paragraph 7.1.5.2.3.2***. ***Paragraph 7.1.5.2.5.1*** and ***Paragraph 7.1.5.2.5.4*** state the vehicular access shall have at least 6.1 m unobstructed width, at least 4.1 m unobstructed height and a dead end vehicular access in excess of 46 m in length is not allowed. The building can achieve the requirements.

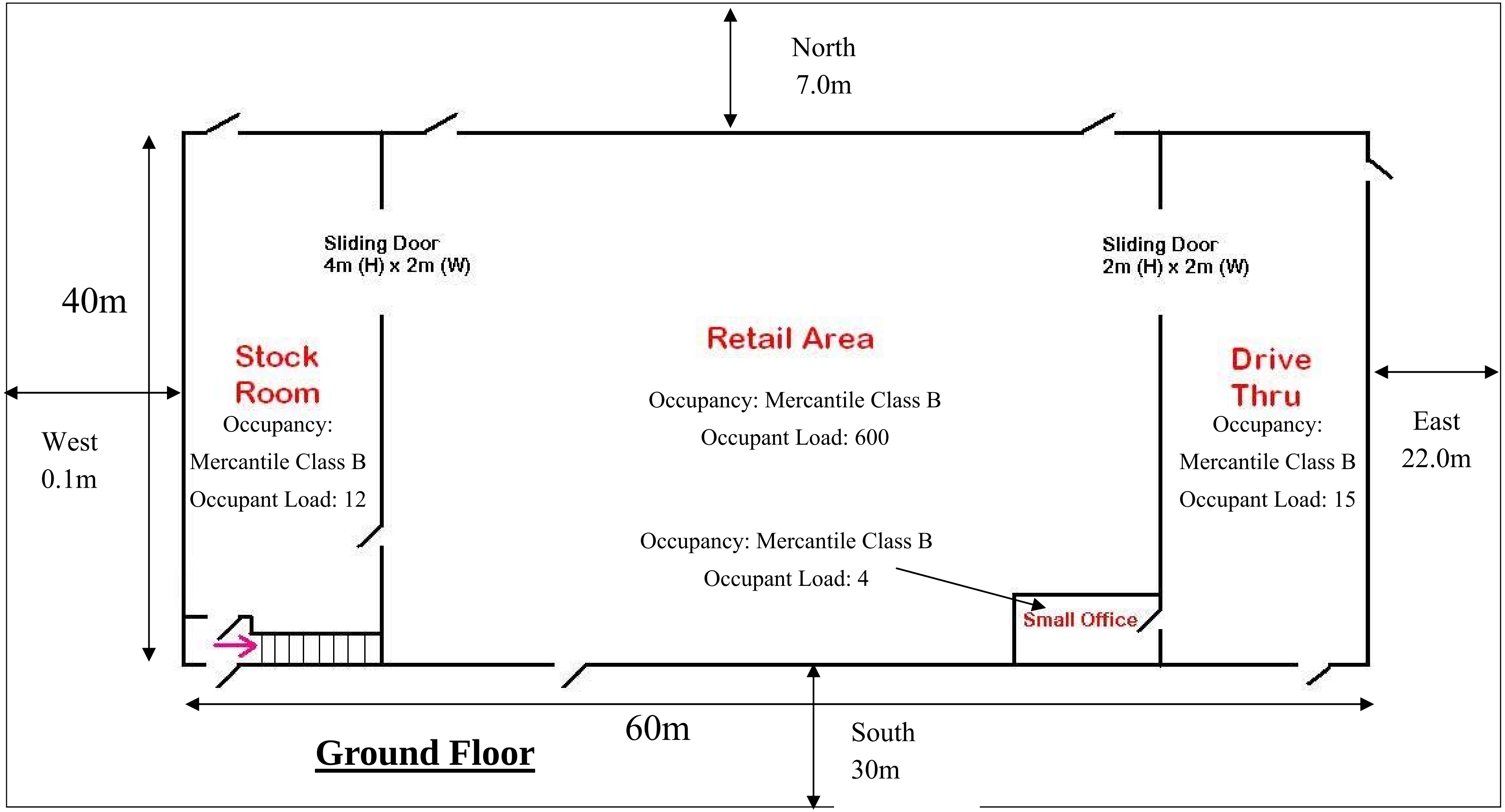
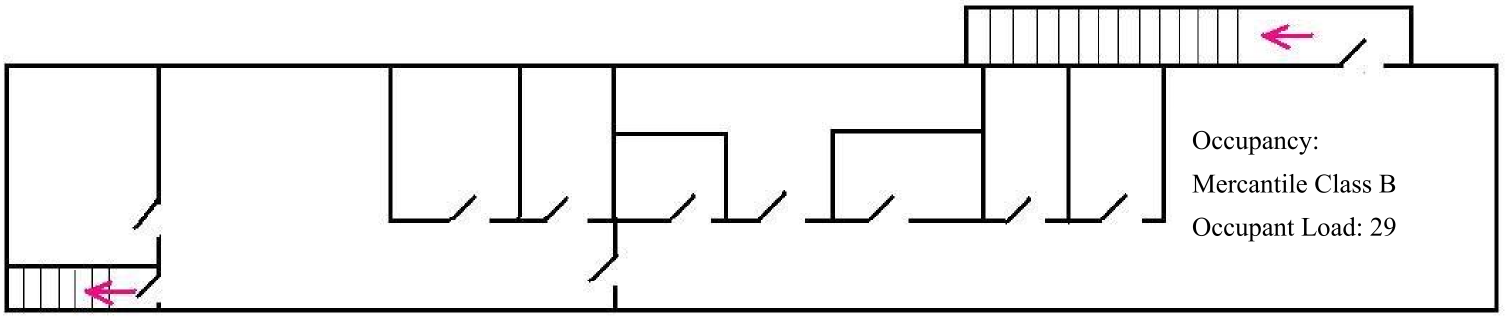


Figure A1-1: Building layout, relevant boundary, occupancy type and occupant load on ground floor



Mezzanine

Figure A1-2: Activity, occupancy type and occupant load in ground floor on mezzanine floor

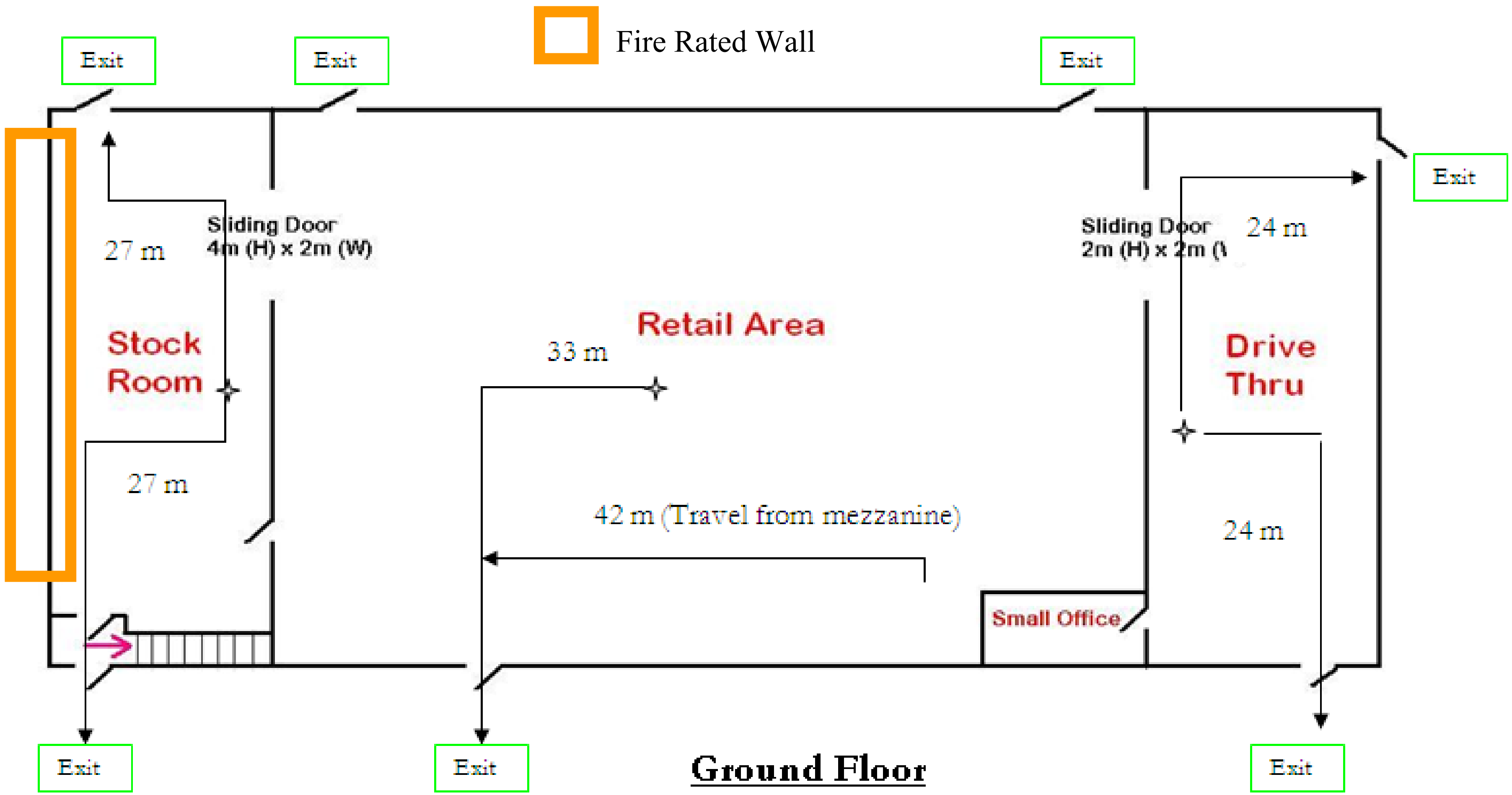


Figure A1-3: Fire rated wall, exits and egress routes on ground floor

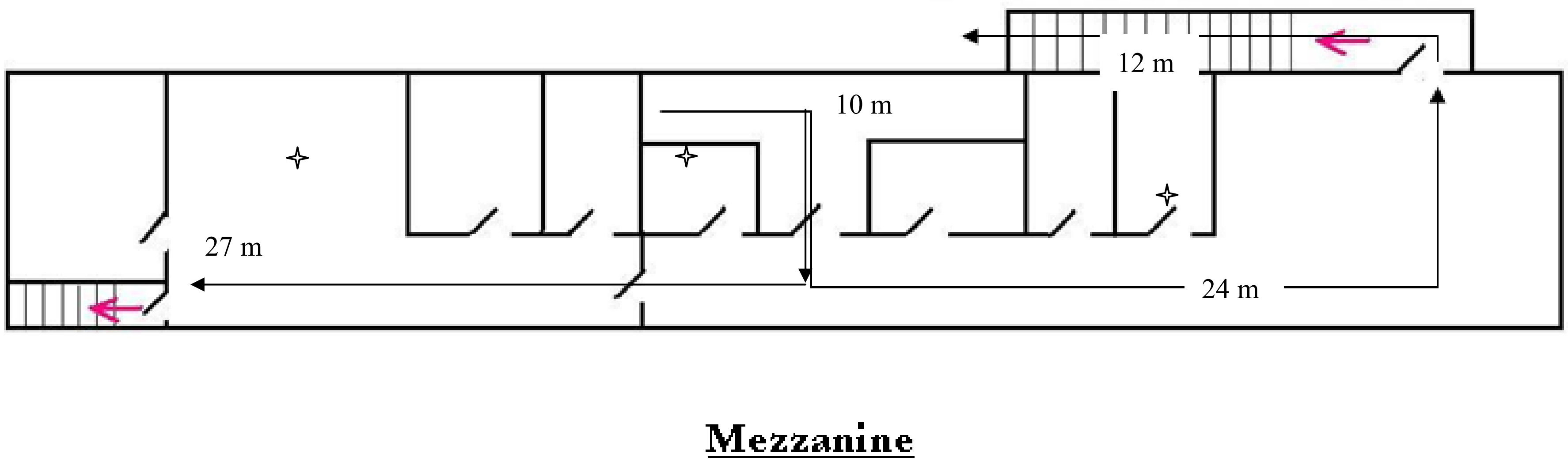


Figure A1-4: Exits and egress routes on mezzanine floor

Appendix A2: Hospital

A2.1 Introduction

The purpose of this appendix is to identify minimum requirements for the hospital as mandated by NFPA 5000 Building Construction and Safety Code (the Code) and provides design suggestions to areas where the building cannot meet the provisions of the Code. The report summarises and identifies the minimum fire protection and life safety requirements contained in the code and standards applicable to the building. This report refers to ***Paragraph, Section*** and ***Table*** with the same numbering as the Code unless stated otherwise.

A2.2 Building Description

The building is a four storeys hospital providing sleeping accommodations for their occupants. The occupants are mostly suffering from physical or mental disability and may not be capable of self-preservation. The building is occupied as a 24 hour basis for the occupants throughout the year and staffs are required to intervene in fire safety functions in all patient-occupied area.

Floors 2 to floor 4 contain inpatients accommodation and treatment facilities. They access to lower floors through stairways and lifts. Floor 1 is mainly for outpatients. The overall building is 104 m wide, 102 m long and 9.6 m height. Each floor has floor to floor height of 2.4 m. The activities within the building are summarised in Table 5-1 and the building layout is provided in Figure A2-1.

Table A2-1: Description of Building

Floor	Activities	Detail
4	Psychiatric units, Social work and sleeping suits	Inpatients and staffs
3	Staff residential areas, cancer centre, ICU and sleeping suits	Inpatients and staffs
2	Laboratory, storage area, surgical suits and sleeping suits	Inpatients and staffs
1	Kitchen, cafeteria, storage areas, gift shop, emergency area, admitting, outpatient service, physiotherapy and business offices	Outpatients and staffs

A2.2.1 Occupancy Classifications, Hazard Contents and Occupant Load

Offices, treatment, diagnostic facilities, ambulatory care facilities, medical clinics, kitchen, cafeteria, hostel and similar facilities that are intended solely for outpatient care (not intended to serve health care occupancies for purposes of housing, treatment, or customary access by patients incapable of self-preservation) shall be separated from areas of Health Care Occupancies by construction having a minimum fire resistance rating in accordance with ***Table 6.2.4.1*** (vertically and horizontal aligned – walls and floors) as per ***Paragraph 19.1.2.4*** and shall be permitted to be classified as other occupancies as per ***Paragraph 19.1.2.2*** and ***19.1.2.3***.

A2.2.1.1 Multiple Occupancies

The primary use of the hospital is for health care purposes and ***Section 6.1*** classifies the overall building occupancy as a Health Care Occupancy. The hospital contains criteria for classifying spaces as other occupancies. The building contains multiple occupancies and they can be protected either as mixed occupancies or as separated occupancies as per ***Paragraph 6.2.1.1***.

Paragraph 19.1.2.4 does not permitted multiple occupancies protected as mixed occupancies in the hospital. The provisions of **Paragraph 19.1.2.4** require occupancies other than Health Care Occupancies shall be completely separated from Health Care Occupancies in accordance with **Paragraph 6.2.4** and **Table 6.2.4.1**.

The main area on ground floor including Physiotherapy, doctors' offices and diagnostic imaging area are classified as Business Occupancies because their intensions are solely for outpatient care as per ***Paragraph A.19.1.2.2***.

The emergency area is classified as Ambulatory Health Care Occupancies because it provides services or treatment simultaneously to four or more patients who are incapable of taking action for self-preservation under emergency conditions without the assistance of others and the area is primarily intended to provide outpatient services as per ***Paragraph 19.1.2.3***.

Kitchen and cafeteria are classified as Assembly Occupancies.

Hostel (staff residential area) on Floor 3 is classified as Hotels and Dormitory Occupancies.

Purchasing store, gas cylinder storage and gift shop on ground floor are classified as Storage Occupancy and contains 13, 3 and 4 occupants respectively. ***Paragraph 6.2.1.3*** allows Storage Occupancy incidental within Business Occupancy because the occupant load and areas are comparatively minor. Storage area on floor 2 is incidental within Health Care Occupancy.

A2.2.1.2 Separated Occupancies

The other occupancies are required to be separated from the Health Care Occupancies by construction having a minimum 2 hours fire resistance rating (vertically and horizontal aligned).

Assembly Occupancies, Business Occupancies and Ambulatory Occupancies are located at the level of discharge and have a 2-hour fire resistance-rated floor/ceiling assembly separating the first and second stories (separating the health care occupancy from the other occupancies) in accordance with ***Paragraph 19.1.2.2***.

Kitchen and cafeteria with occupants less than 300 people are classified as Assembly Occupancies and have a 2-hour fire resistance rating in accordance with ***Table 6.2.4.1(b)*** separating the Assembly Occupancies and Business Occupancies as per ***Paragraph 19.1.2.2***, ***19.1.2.3*** and ***19.1.2.7***.

The emergency area is classified as Ambulatory Health Care Occupancies and has a 2-hour fire resistance rating in accordance with ***Table 6.2.4.1(b)*** separating the Ambulatory Health Care and Business Occupancies as per ***Paragraph 19.1.2.2***, ***19.1.2.3*** and ***19.1.2.7***.

The hostel on floor 3 is classified as Hotels and Dormitory Occupancies and has a 2-hour fire resistance rating in accordance with ***Table 6.2.4.1(b)*** separating the Hotels and Dormitory Occupancies and Health Care Occupancies as per ***Paragraph 19.1.2.2***, ***19.1.2.3*** and ***19.1.2.7***.

Paragraph 6.2.1.2 states that egress routes from occupancy to involve traverse through doors in the separating construction into the other occupancy is not permitted in separated occupancy. The required means of egress from occupancy are provided by independent exits. The door openings from kitchen and cafeteria to the other occupancy are convenient extras and are not used as exit access. The hostel on floor 3 is permitted to have their sole means of egress pass through a non-residential occupancy, such as Health Care Occupancies, as per ***Paragraph 24.1.3.2.1*** because the hospital is sprinkler protected.

Health Care Occupants are permitted to egress from Health Care Occupancies to other occupancies provided that non-health-care areas are conformed to the Health Care Occupancies requirements as per ***Paragraph 19.1.2.5***. However, if the non-Health Care Occupancies that do not conform with Health Care Occupancies egress provisions, occupants egress from Health Care Occupancies to other occupancies through a horizontal exit in accordance with ***Paragraph 19.2.2.5*** is permitted provided that the occupancy does not contain high hazard contents exceeding the maximum allowable quantities per control area as set forth in ***Paragraph 34.1.3***, other than Level 4 hazardous areas, as per ***Paragraph 19.1.2.5.1***. The requirements for horizontal exit are listed section 6.6 of this Appendix.

A2.2.1.3Mixed Occupancies

The other occupancies are not required to be separated from the Health Care Occupancies by construction having a minimum 2 hours fire resistance rating. The most restrictive life safety requirements applicable to any one occupancy present would be required for all the occupancies.

Occupancies other than Health Care Occupancies are not permitted to be protected as mixed occupancies as per **Paragraph 19.1.2.4**.

A2.2.2 High Hazard Contents

Gas cylinder storage on floor 1 and laboratory and storage area on floor 2 contain flammable liquids, hazardous chemicals, combustible materials and flammable gases that are likely to burn with extreme rapidity. The materials in the areas are defined as High Hazard Level 2 Contents as per ***Paragraph 6.3.2.4.3***.

A2.2.3 Occupant Load Factors

Occupant load factors are expressed in terms of square meters per person. The Code uses occupant load factors to determine the allowable number of occupants in a given area and also allows the occupant load to be increased above the calculated number provided the other egress provisions are met and the occupant load does not exceed 0.46 m^2/person. The occupant load is calculated from relevant occupant load factors taken from ***Table 11.3.1.2***.

The classification of Hazard of Contents for the building has been taken from ***Section 6.3.2***. The occupancy classification, fire hazard classification, area and occupant load are detailed in Table A2-2. The overall activity, occupancy type and occupant load are included in Figure A2-1 to Figure A2-4.

Table A2-2: Classification of Occupancy, Hazard of Contents and Occupant Load

Floor	Activity	Occupancy	Fire Hazard	Occupant Density (m^2 per person)	Gross Area (m^2)	Occupant Load for Egress (persons)
4	Psychiatric-1	Health Care	Ordinary	9.3	322	35
	Psychiatric-2	Health Care	Ordinary	9.3	432	47
	Offices	Health Care	Ordinary	9.3	669	72
	Sleeping suites	Health Care	Ordinary	22.3	892	40
				Floor 4 total		**194**
3	Hostel-1	Residential	Ordinary	18.6	322	18
	Hostel-2	Residential	Ordinary	18.6	432	24
	Sleeping rooms	Health Care	Ordinary	22.3	713	32
	Sleeping suites	Health Care	Ordinary	22.3	1003	45
				Floor 3 total		**119**
2	Laboratory	Health Care	High	22.3	892	96
	Storage area	Health Care	High	46.5	490	11
	Inpatient pharmacy	Health Care	Ordinary	22.3	223	10
	Non-sleeping suites	Health Care	Ordinary	22.3	669	30
	Sleeping suites	Health Care	Ordinary	22.3	892	40
				Floor 2 total		**187**

Floor	Activity	Occupancy	Fire Hazard	Occupant Density (m^2 per person)	Gross Area (m^2)	Occupant Load for Egress (persons)
1	Gas Cylinder Storage	Business	High	46.5	129	3
	Kitchen	Assembly	Ordinary	9.3	530	57
	Cafeteria	Assembly	Ordinary	1.4	280	200
	Purchasing store	Business	Ordinary	27.9	360	13
	Emergency	Ambulatory Health Care	Ordinary	9.3	558	60
	Outpatient	Business	Ordinary	9.3	1134	122
	Gift Shop	Business	Ordinary	27.9	92	4
	Offices	Business	Ordinary	9.3	1739	190
	Physiotherapy	Business	Ordinary	9.3	625	68
				Floor 1 total		**717**
				Total		**1217**

A2.2.4 High Rise Building

The floor height measured from the lowest level of fire department vehicle access to the highest floor of an occupied story is not greater than 23 m. The building is not considered as a high rise building as defined in ***Paragraph 3.3.64.10***.

A2.3 Construction

A2.3.1 Type of Construction

The external constructions are concrete walls and the internal constructions are gypsum boards. Buildings and structures shall be classified according to their type of construction as per ***Paragraph 7.2.1.1***. NFPA 220, Standard on Types of Building Construction, shall be used to determine the requirements for the construction classification. Concrete wall and gypsum are classified as Type II construction because they are non-combustible or limited combustible material as per ***Paragraph 7.2.3.1***. The construction of the building is Type II construction.

The north wall of the building is 15 m from the property line, 20 m to the East, 50 m to the South and 20 m to the West. All exterior walls are not required to have a fire resistance rating as per ***Table 7.3.2.1***. For a separation distance between the building and the property line of less than or equal to 3 m, exterior walls are required to have a fire resistance rating.

A2.3.2 Allowable Building Height and Area

The hospital is a four stories building. The height of the building is 9.6 m and the largest area per story is 8821 m^2. The building is constructed with Type II (222) and has achieved the height and area requirements as per ***Table 7.4.1***. The table establishes building construction type limitations based on the total number of stories in a building and stories in height. It is applied to health care occupancies by starting the story count with the level of exit discharge and ending with the highest occupiable story, even if that story is not used as a health care occupancy.

The code regulates the height and area of buildings based on occupancy of the building and construction type. ***Table 7.4.1*** has no limitation on the area of the Health Care Occupancy of Type II (222) construction but limits the number of stories and building height to 12 stories and 54.8 m.

The building is classified as a four story building and has 8821 m^2 floor area. The building achieved the allowable height and area requirements. The allowable height and area are summarised in Table A2-3.

Table A2-3: Allowable Height and Area

	Actual	**Allowable (*Table 7.4.1*)**	**Increase for Sprinklers (*Table 7.4.1*)**
Health Care Occupancies - Type of Construction: Type II (222)			
Building Height (m)	9.6	48.7	54.8
Building Height (Stories)	4	Not permitted	12
Building Area (m^2)	3951	Unlimited	Unlimited
Ambulatory Health Care Occupancies - Type of Construction: Type II (222)			
Building Height (m)	2.4	48.7	54.8
Building Height (Stories)	1	11	12
Building Area (m^2)	845	Unlimited	Unlimited
Assembly Occupancies (<300) - Type of Construction: Type II (222)			
Building Height (m)	2.4	48.7	54.8
Building Height (Stories)	1	7	12
Building Area (m^2)	810	Unlimited	Unlimited

	Actual	Allowable (*Table 7.4.1*)	Increase for Sprinklers (*Table 7.4.1*)
Storage Occupancies - Type of Construction: Type II (222)			
Building Height (m)	4.8	48.7	54.8
Building Height (Stories)	2	11	12
Building Area (m^2)	1390	14630	14630
Business Occupancies - Type of Construction: Type II (222)			
Building Height (m)	2.4	48.7	54.8
Building Height (Stories)	1	11	12
Building Area (m^2)	7166	Unlimited	Unlimited
Hotels and Dormitory Occupancies - Type of Construction: Type II (222)			
Building Height (m)	7.2	48.7	54.8
Building Height (Stories)	3	11	12
Building Area (m^2)	754	Unlimited	Unlimited

A2.4 Life Safety System Requirements

A2.4.1 Automatic Sprinkler System

The building is protected by an approved, electrically supervised automatic sprinkler system in accordance with NFPA 13 and ***Section 55.3*** as per ***Paragraph 19.3.5.1*** (refer to the plan in Figure A2-5 to Figure A2-8 for the location of sprinklers).

For Assembly Occupancies serve more than 50 people and are protected by an approved automatic sprinkler system.

Listed quick-response or listed residential sprinklers are used throughout smoke compartments containing sleeping patient as per ***Paragraph 19.3.5.3***.

Hostel rooms or suites on floor 3 are protected by listed quick-response sprinklers as per ***Paragraph 24.3.5.7***.

A2.4.2 Automatic Smoke Detection System

Paragraph 19.3.6.1 states spaces that open to the corridor shall meet the following criteria:

- Spaces are not used for patient sleeping rooms, treatment rooms, or hazardous areas
- Spaces are for nurses' stations

- An electrically supervised automatic smoke detection system is installed in the open space
- The corridors onto which the spaces open in the same smoke compartment are protected by an electrically supervised automatic smoke detection system or the entire space is protected throughout by quick response sprinklers
- Waiting area is protected by an electrically supervised automatic smoke detection system and is less than 55.7 m^2. It is permitted to be open to the corridor as per Paragraph 19.3.6.1(2)

All sleeping suites (less than 465 m^2) are provided with total coverage (complete) automatic smoke detection system in accordance with NFPA 72 as per ***Paragraph 19.2.5.7.2.1(C)(2)*** and ***Paragraph 19.2.5.7.2.3(A)*** (refer to the plan in Figure A2-5 to Figure A2-8 for the location of smoke detectors).

All sleeping suites (greater than 465 m^2 and not exceeding 700 m^2) are provided with total coverage (complete) automatic smoke detection system and direct visual supervision as per ***Paragraph 19.2.5.7.2.1(C)(2)*** and ***Paragraph 19.2.5.7.2.3(B)***.

Hostel rooms and suites on floor 3 require smoke alarms to be installed in every room as per ***Paragraph 24.3.4.9***. Smoke alarm system is not required in the corridor because the building is protected by sprinkler system as per ***Paragraph 24.3.4.8***.

A2.5 Fire Protection Requirements

A2.5.1 Internal Spread of Fire and Smoke

A2.5.1.1 Hazardous Areas

Gas cylinder storage room, storage room and gift shop on ground floor, storage room and laboratory on floor 2 may contain hazard of contents classified higher than that of the health care occupancy. Those areas are protected with at least one hour fire separation in accordance with ***Section 19.3.2*** and ***Table 19.3.2.1*** as per ***Paragraph 19.1.2.8***. The amounts of high hazard contents in other areas do not exceed maximum allowable quantity as set forth in ***Paragraph 34.1.3*** and they are not permitted to be contained in the hospital as per ***Paragraph 19.1.2.9***. High hazard contents are not required to comply with the protection levels as set forth in ***Section 34.3***.

Examples of suites that might be hazardous areas are medical records, pharmaceutical suites, storage room larger than 4.6 m^2 and storing combustible material. Hazardous areas are protected in accordance with ***Section 19.3.2*** and ***Table 19.3.2.1***.

Hazardous areas within a suite shall not be required to be separated from the remainder of the suite by walls and doors provided that the requirements from ***Paragraph 19.2.5.7.1.3(C)*** are satisfied and are listed as follows:

- The suite is primarily a hazardous area
- The suite is protected by an approved automatic smoke detection system
- The suite is separated from the rest of the health care facility as required for a hazardous area by ***Paragraph 19.3.2.1***

A2.5.1.2 Suites

Suites are separated from both the corridor and the adjacent room by walls and doors in accordance with ***Paragraph 19.2.5.7.1.2***. Walls and partitions within the suite subdivide the space with limited-combustible gypsum board meeting the requirements for ***Paragraph 19.2.5.7.1.4***. Intervening rooms are not hazardous areas as defined by ***Paragraph 19.3.2*** and no separation is required within a suite.

A2.5.1.3 Subdivision of Building Spaces

Section 19.3.7 mandates every story used by inpatients for sleeping or treatment or every story having an occupant load of 50 or more persons is subdivided into not less than two smoke compartments. Each smoke compartment is divided by smoke barriers and the area is limited to 2100 m^2 as per ***Paragraph 19.3.7.1.3***. The smoke barrier subdivision requirements from above are not included areas that do not contain a Health Care Occupancy and that are separated from the health care occupancy by a fire barrier as per ***Paragraph 19.3.7.1.6***.

Every story from Floor 2 to floor 4 is subdivided into three smoke compartments because of the 2100 m^2 area limitation. The smoke barrier subdivision requirements is not required on floor one because the occupancies on floor one do not contain any Health Care Occupancies and are separated from the health care occupancy by a fire barrier. Smoke barriers have a minimum 1-hour fire resistance rating as per ***Paragraph 19.3.7.2***.

Cross-corridor openings in smoke barriers are a pair of swinging doors or horizontal sliding door except they are not in required means of egress as per ***Paragraph 19.3.7.4*** and ***19.3.7.6***. A pair of swing door swings in a direction opposite from the other and each door is provided at least 1.055 m in width. The minimum width of horizontal sliding door is 2.11 m. All doors in smoke barriers are self-closing or automatic-closing and vision panels consisting of fire-rated glazing or wired glass panels in approved frames is provided as per ***Paragraph 19.3.7.7*** and ***19.3.7.8***.

Hostel suites are separated from each other by walls constructed as fire barriers having fire resistance rating of not less than 0.5 hour as per ***Paragraph 24.3.7.2***.

Emergency area is separated from other occupancies by one hour fire resistance rating walls and 20 minute fire resistance rating doors as per ***Paragraph 20.3.7.1***. Smoke barriers are not required in the emergency area because the area is less than 929 m^2 and the building is protected throughout by an approved electrically supervised automatic sprinkler system as per ***Paragraph 20.3.7.2(2)***.

Paragraph 6.2.1.2 does not permit occupants from Emergency area (Health Care Occupancies) travel to other occupancy because they are protected as separated occupancy. However, ***Paragraph 20.3.7.2(3)(c)*** allows occupants from Emergency area access to the other occupancy if the following criteria are met:

- The emergency area is less than 2100 m^2
- A 1-hour fire resistance rated smoke barrier is separating the emergency area and a neighbouring tenant space of some other occupancy classification as per ***Paragraph 20.3.7.4.1***
- The travel distance from any point to reach a door in a smoke barrier is not exceeding 61 m as per ***Paragraph 20.3.7.3***

A2.5.1.4 Vertical Openings

Section 8.12 states that enclosures connecting four stories or more shall provide at least two hour fire barrier and construct as a smoke barrier to restrict the passage of smoke. Elevators and enclosed stairways are provided the above criteria.

A2.5.1.5 Vertical Exit Enclosures

Vertical exit enclosures such as interior exit stairways shall be enclosed with fire barriers. Exit enclosures shall have a fire resistance rating not less than one hour where connecting less than four stories and not less than two hour where connecting four stories or more as per ***Section 11.1.3.2***.

Occupants are able to travel from upper floors to ground floor through an enclosed stairway and access directly to outside. The enclosed stairways are required to achieve at least one hour fire resistance rating as per ***Paragraph 11.1.3.2.1.1***. The enclosed stairway acts as a vertical shaft, 2 hour fire resistance rating is required for walls and 1.5 hour fire resistance rating is required for fire door assemblies as per ***Table 8.7.2***.

A2.5.1.6 Corridors

Although ***Paragraph 11.1.3.1*** states that corridor used as exit access and serving more than 30 occupants are required to be separated from other parts of the building by walls having at least one hour fire resistance rating. All openings to the corridor are protected by fire door assemblies equipped with door closers.

For Business Occupancies and Health Care Occupancies, corridor that serves as an escape route to an exit is not required any fire resistance rating because the building is protected by an approved automatic sprinkler system as per ***Paragraph 28.3.6.1(3)*** and ***19.3.6.2***.

Corridor in Hotels and Dormitory Occupancies (hostel on floor 3) is required not less than 0.5 hour fire resistance rating as per ***Paragraph 24.3.6.2***.

A2.5.1.7 Horizontal Exits

Horizontal exits separating building or areas shall provide at least 2-hour fire resistance rating as per ***Paragraph 11.2.4.3.1***.

A2.5.1.8Miscellaneous Requirements

An exitpassageway is connected to the bottom of a staircase to an outside exit door. The exitpassageway is separated from other parts of the building by having the same fire resistance rating (2 hours) as the stair enclosure as per ***Paragraph 11.2.6.4 and Section 11.7***.

The overall interior passive fire protection requirements are given in Figure A2-5 to Figure A2-8.

A2.5.2 External Spread of Fire and Smoke

The minimum fire resistance ratings for Type II (222) construction are given in ***Table 7.2.1.1*** and ***Table 7.3.2.1***, whichever is greater as per ***Paragraph 7.3.2.1***.

Paragraph 7.3.9 specified the requirements for vertical separation of exterior openings. The building does not require vertical separation of exterior openings as per ***Paragraph 37.1.4.1***.

Allowable area of unprotected openings for the North, East and South walls have not been exceeded that permitted by ***Table 7.3.5(b)*** because they are not required to have a fire resistance rating as determined by ***Table 7.3.2.1*** as per ***Paragraph 7.3.5***. The West wall needs to be fire rated for two hours and there is no allowable area of unprotected openings to be tested by ***Table 7.3.5(b)***. ***Paragraph 7.3.5*** is complied. The applicable data is summarised in Table A2-4 and Table A2-5.The distance to the relevant boundary is shown in Figure A1-1.

Table A2-4: Fire Resistance Rating Requirements for Exterior Walls on Fire Separation Distance

Location	Enclosing rectangle H x W (m)	Distance to the relevant Boundary (m)	Fire Resistance rating (hr)	Percentage of Unprotected Areas	
				Allowed[1] (%)	Actual (%)
North Wall	70 x 9.6	15	2	100	20 - OK
East Wall	35 x 9.6	20	2	100	20 - OK
South Wall	46 x 9.6	50	2	100	20 - OK
West Wall	102 x 9.6	20	2	100	20 - OK

Note 1: The allowable unprotected areas of the external walls have been addressed using

Table 7.3.5(b) and are permitted to be doubled as per ***Paragraph 7.3.5.5.1***.

Table A2-5: Fire Resistance Rating Requirements for Building Elements

Building Element	Fire Separation Distance (m)	Required Rating (Hours)	Detail
Bearing Walls			
Exterior			
North	15	2	***Table 7.2.1.1*** and ***7.3.2.1***
East	20	2	
South	50	2	
West	20	2	
Interior	-	2	***Table 7.2.1.1***
Non Bearing Walls and Partitions			
Exterior			
North	15	0	***Table 7.2.1.1***
East	20	0	
South	50	0	
West	20	0	
Interior	-	0	
Floor Construction	-	2	***Table 7.2.1.1***
Roof construction	-	1	***Table 7.2.1.1***
Columns, Beans, Girders, Trusses and Arches	-	2	***Table 7.2.1.1***
Occupant Separation	-	1	Assembly, Health Care, Ambulatory Health Care, Residential and Business
Corridor Separation	-	0.5	Hostel Corridor
Fire Wall Separation	-	2	Exit passageway
		1	Hazard Area
		0.5	Between hostel suites
Vertical openings	-	2	Elevators and enclosed stairways
Smoke Barrier Separation	-	1	Smoke compartment
Horizontal exit	-	2	Serves as an exit
Shafts for exit	-	2	Enclosed stairways
Shafts for other	-	2	Elevators

A2.6 Means of Escape

A2.6.1 Exits

The minimum number of exits is generally based on ***Section 11.4.1***. All rooms and spaces within each story shall be provided with and have access to the minimum number of exits as follows (refer to Figure A2-9 to Figure A2-11 for the location of exits):

- Under 500 occupants requires a minimum of two exits
- 500 occupants to 1000 occupants requires a minimum three exits
- Over 1000 occupants requires a minimum four exits

Every story provided more than two exits to meet the requirement of ***Paragraph 19.2.4.1***. Each smoke compartment on floor 2 to floor 4 has accessed to two separate exits, with one of the exits is not horizontal exit, to satisfy the provision of ***Paragraph 19.2.4.2***. For smoke compartment does not have an exit, egress is permitted through an adjacent compartment(s) providing that egress not require return through the smoke compartment of fire origin as required by ***Paragraph 19.2.4.3***. Occupants on floor 2, 3 and 4 are able to enter an enclosed exit stair on that floor without travelling to another floor to reach the entrances to the exits. The building has met the minimum number of exits requirements in accordance with ***Section 19.2.4***.

Sleeping rooms of more than 93 m^2 are provided two exit access doors remotely located (two exit access doors are separated by a distance, d, that is at least one-third the room diagonal measurement, D, because the building is sprinklered) form each other as per ***Paragraph 19.2.5.5.1*** and ***Paragraph 19.2.5.7.2.2(A)***.

Non-sleeping rooms of more than 230 m^2 on floor 2, floor 3 and floor 4 are provided two exit access doors remotely located from each other as per ***Paragraph 19.2.5.5.2***.

Each suite in the Hostel on floor 3 is provided with two exit access doors remotely located from each other as per ***Paragraph 24.2.5.8*** because the area of suite is more than 185 m^2.

Each room in the Emergency area on floor 1 is provided with one exit access door as per ***Paragraph 20.2.4.2*** because the area of suite is more than 232 m^2. There are two exits provided in the Emergency area to satisfy the provisions of ***Paragraph 20.2.4.1*** and ***20.2.4.3***: (1) Direct egress to the outside of building and (2) Egress from the area through the fire rated smoke barrier and travel along the corridor within Business Occupancy to the outside of building. The egress from the Emergency area through the fire rated smoke egress into a corridor leading to a pubic place is permitted by ***Paragraph 20.1.2.4*** as long as the corridor is complied with the requirements set forth in Business Occupancies and the Emergency area is satisfied the subdivision requirements from ***Section 20.3.7***. The most restrictive fire and life safety requirements of Ambulatory Health Care Occupancies and Business Occupancies are not applied to each other.

A2.6.2 Single Means of Egress Requirements

Single means of egress is permitted in Business Occupancies and is detailed in ***Paragraph 28.2.4.2***. Several exceptions are allowed but none of the exceptions are relevant to the building.

Single means of egress is permitted in Hotel and Dormitory Occupancies and is detailed in ***Paragraph 24.2.4.2***. Several exceptions are allowed but none of the exceptions are relevant to the building.

Single means of escape is allowed in Mercantile Occupancies as per the requirement of ***Paragraph 27.2.4*** but none of the area in the building is relevant to the requirement.

A2.6.3 Suites

A2.6.3.1 Sleeping Suites for patient care

Sleeping suites (not included individual bathrooms, closets and briefly occupied work spaces such as control rooms in radiology and small storage rooms in a pharmacy) have exit access to a corridor without having to pass through more than one intervening room as per ***Paragraph 19.2.5.7.2.1(A)***.

Sleeping suites of more than 93 m^2 are provided two exit access doors remotely located (two exit access doors are separated by a distance, d, that is at least one-third the room diagonal measurement, D, because the building is sprinklered) form each other as per ***Paragraph 19.2.5.5.1*** and ***Paragraph 19.2.5.7.2.2(A)***.

Sleeping suites of more than 93 m^2 have two exit access doors remotely located from each other (one of the two means of egress is permitted to be into another suite where 30 m travel distance to an exit access door is applied only to the original suite) as per ***Paragraph 19.2.5.7.2.2(A)*** and ***19.2.5.7.2.2(C)***.

For sleeping suites of less than or equal to 93 m^2, one means of egress from the suite is permitted provided that the egress is directly to a corridor as per ***Paragraph 19.2.5.7.2.2 (B).***

Constant staff supervision is provided with the sleeping suits as per ***Paragraph 19.2.5.7.2.1(B)***.

A2.6.3.2 Sleeping Suites not for patient care and non patient care suites

The egress provisions for non-patient care suites shall be in accordance with the primary use and occupancy of the space, except that in no case shall the maximum travel distance to an exit form within the suite exceed 61 m as per ***Paragraph 19.2.5.7.4***.

A2.6.3.3 Non Sleeping Suites for patient care

Non sleeping suites (not included individual bathrooms, closets and briefly occupied work spaces such as control rooms in radiology and small storage rooms in a pharmacy) have exit access to a corridor without having to pass through more than two intervening room as per ***Paragraph 19.2.5.7.3.1***.

Non sleeping suites of more than 232 m^2 have two exit access doors remotely located from each other (one of the two means of egress is permitted to be into another suite and it is not consider intervening room) as per ***Paragraph 19.2.5.7.3.2(A) and Paragraph 19.2.5.7.3.2(C)***.

For non sleeping suites of less than or equal to 232 m^2, one means of egress from the suite is permitted provided that the egress is directly to a corridor as per ***Paragraph 19.2.5.7.3.2(B)***.

Non-sleeping suite maximum size is 929 m^2 as per ***Paragraph 19.2.5.7.3.3***.

A2.6.4 Length of Escape Routes

A2.6.4.1 Health Care Occupancies

A2.6.4.1.1 Dead-ends Corridors

Paragraph 19.2.5.2 states that dead-end corridors shall not exceed 9.1 m for sprinklered building. Each area in the building provides at least two means of egress. Neither of them is associated with corridors and no other dead ends existed.

A2.6.4.1.2 Common Path of Travel

Paragraph 19.2.5.3 limits the common path of travel to 30 m or less for sprinklered building. Common path of travel is the portion of the means of egress that must be traversed until such a point that at least two independent means of egress to at least two exits are available. The building complied with the common path of travel provisions.

A2.6.4.1.3 Travel Distance

Paragraph 19.2.6.2.1 requires the maximum travel distance measured between any point in a room and an exit is not exceeding 61 m for sprinklered building. Travel distance between any point in a health care sleeping room and an exit access door in that room is not exceeding 15 m as ***per Paragraph 19.2.6.2.2***. The travel distance from any point to reach a door in the required smoke barrier is not exceeding 61 m as per ***19.3.7.1.5***.

Travel distance between any point in a sleeping suite and an exit access door from that suite are not exceed 30 m. Travel distance between any point in a sleeping suite and an exit are not exceed 61 m as per ***Paragraph 19.2.5.7.2.4***.

Travel distance between any point in a non sleeping suite and an exit access door from that suite are not exceed 30 m with one intervening room and 15 m with two intervening room. Travel distance between any point in a non sleeping suite and an exit are not exceeding 61 m. as per ***Paragraph 19.2.5.7.3.4***.

A2.6.4.2 Assembly Occupancies

A2.6.4.2.1 Dead-ends Corridors

Paragraph 16.2.5.1.2 states that dead-end corridors shall not exceed 6.1 m for sprinklered building. Each area in the building provides at least two means of egress. Neither of them is associated with corridors and no other dead ends existed.

A2.6.4.2.2 Common Path of Travel

Paragraph 16.2.5.1.3 limits the common path of travel to 6.1 m or less for sprinklered building. Common path of travel is the portion of the means of egress that must be traversed until such a point that at least two independent means of egress to at least two exits are available. The building complied with the common path of travel provisions.

A2.6.4.2.3 Travel Distance

Paragraph 16.2.6.2 requires the maximum travel distance measured between any point in a room and an exit is e not exceeding 76 m for sprinklered building. The travel distance in the Assembly Occupancies are less than or equal to 76 m. Travel through kitchen, store room or hazardous areas are not permitted as per ***Paragraph 16.2.5.2***.

A2.6.4.3 Business Occupancies

A2.6.4.3.1 Dead-ends Corridors

Paragraph 28.2.5.2.1 states that dead-end corridors shall not exceed 15 m for sprinklered building. Each area in the building provides at least two means of egress. Neither of them is associated with corridors and no other dead ends existed

A2.6.4.3.2 Common Path of Travel

Paragraph 28.2.5.3.1 limits the common path of travel to 30 m or less for sprinklered building. Common path of travel is the portion of the means of egress that must be traversed until such a point that at least two independent means of egress to at least two exits are available. The building complied with the common path of travel provisions.

A2.6.4.3.3 Travel Distance

Paragraph 28.2.6.1 requires the maximum travel distance measured between any point in a room and an exit is not exceeding 91 m for sprinklered building. The travel distance in the Business Occupancies are less than or equal to 91 m.

A2.6.4.4 Ambulatory Health Care Occupancies

Emergency area is classified as Ambulatory Health Care Occupancies and is complied with the provision of business occupancy and ambulatory health care occupancy, whichever are more stringent as per ***Paragraph 20.1.1.1.4***. The arrangement of dead-end corridors and common paths of travel are in accordance with ***Paragraph 28.2.5.2.1*** and ***28.2.5.3.1***.

A2.6.4.4.1 Dead-ends Corridors

Paragraph 28.2.5.2.1 states that dead-end corridors shall not exceed 15 m for sprinklered building. Each area in the building provides at least two means of egress. Neither of them is associated with corridors and no other dead ends existed.

A2.6.4.4.2 Common Path of Travel

Paragraph 28.2.5.3.1 limits the common path of travel to 30 m or less for sprinklered building. Common path of travel is the portion of the means of egress that must be traversed until such a point that at least two independent means of egress to at least two exits are available. The building complied with the common path of travel provisions.

A2.6.4.4.3 Travel Distance

Paragraph 20.2.6.2 requires the maximum travel distance measured between any point in a room and an exit is not exceeding 61 m for sprinklered building. The travel distance in the Ambulatory Health Care Occupancies are less than or equal to 61 m. The travel distance measured between any room door and an exit is not exceeding 45 m as per ***Paragraph 20.2.6.2***.

A2.6.4.5 Hotels and Dormitory Occupancies

There are two non-patient care suites in the hostel on floor 3. The egress provisions are in accordance with Hotels and Dormitory Occupancies, except that in no case shall the maximum travel distance to an exit form within the suite exceed 61 m as per ***Paragraph 19.2.5.7.4***.

A2.6.4.5.1 Dead-ends Corridors

Paragraph 24.2.5.7 states that dead-end corridors shall not exceed 10.7 m for sprinklered building. Each area in the building provides at least two means of egress. Neither of them is associated with corridors and no other dead ends existed.

A2.6.4.5.2 Common Path of Travel

Paragraph 24.2.5.4 limits the common path of travel to 15 m or less for sprinklered building. Common path of travel is the portion of the means of egress that must be traversed until such a point that at least two independent means of egress to at least two exits are available. Travel within the suites is not included when determining the length of the common path of travel as per ***Paragraph 24.2.5.5***. The building complied with the common path of travel provisions.

A2.6.4.5.3 Travel Distance

Paragraph 24.2.6.2 requires the maximum travel distance measured between any point in a room and a corridor door is not exceeding 38 m for sprinklered building. The travel distance in the Hostel are less than or equal to 38 m. The travel distance measured between any room door and the nearest exit is not exceeding 61 m as per ***Paragraph 24.2.6.3.2***.

The maximum escape route lengths are as shown below in Table A2-6. Travel direction and travel distance are detailed in Figure A2-9 to Figure A2-11.

If there are two exits or more in a room, the maximum travel distance in all occupancies is measured from the most remote point in a room to the nearest exit.

Table A2-6: Length of Escape Routes

Area	Occupancy	Dead End Corridor (m)		Common Path (m)		Travel Distance (m)	
		Allowed[1]	Actual	Allowed[1]	Actual	Allowed[1]	Actual[2]
Kitchen	Assembly	6.1	0	6.1	0	76	29
Cafeteria	Assembly	6.1	0	6.1	0	76	30
Sleeping suite	Health Care	9.1	8.5	30	16	61	56
Pharmacy	Health Care	9.1	0	30	29	61	35
Laboratory	Health Care	9.1	0	30	0	61	58
Imaging	Business	15	0	30	15	91	59
Physiotherapy	Business	15	0	30	0	91	67
Office	Business	15	0	30	27	91	71
Emergency	Ambulatory Health Care	15	0	30	12	61	30
Hostel	Hotels and Dormitory	10.7	0	15	0	99	60

Note 1: Approved and supervised automatic sprinkler system is installed throughout the building in accordance with NFPA 13 and ***Paragraph 55.3.2***

Note 2: On entering a protected stairs or exit the occupants are considered to have ended their travel distance

A2.6.5 Arrangement of Means of Egress

As per ***Paragraph 11.5.1.2*** and ***19.2.5.4*** corridor shall provide at least two approved exits and shall provide exit access without passing through any intervening rooms. The building is complied with the Paragraphs.

Access to an exit shall not pass through kitchens; restroom; closets; bedrooms or similar spaces; or other rooms or spaces subject to locking as per ***Paragraph 11.5.2***. ***Paragraph 19.2.5.6.1*** requires every patient sleeping room must have an exit access door leading directly to an exit access corridor and then to an exit, unless otherwise provided below:

- A room has an exit door directly to the outside at the ground floor in accordance with ***Paragraph 19.2.5.6.3***
- A sleeping room with not more than eight patient beds or sleeping suite or non-sleeping suite is permitted to pass through one intervening room to reach an exit access corridor, provided that an approved automatic smoke detection system

is installed in the intervening room, as addressed in ***Paragraph 19.2.5.6.2*** and ***19.2.5.6.4***

The building is equipped throughout with an automatic sprinkler system. ***Section 11.5.1.4*** requires the exits to be separated by at least one-third of the length of the maximum overall diagonal dimension of the building area served, measured in a straight line between the nearest edge of the exits. The building meets the requirement.

A2.6.6 Horizontal Exits

If a horizontal exit serves only in one direction, a single door providing clear width of not less than 1.055 m is required as per ***Paragraph 19.2.2.5.3*** and doors in horizontal exits are required to swing in the direction of egress travel as per ***Paragraph 11.2.4.3.8***, unless one of the following conditions applies:

- In a new hospital, a horizontal exit serves a corridor 2.44 m or more in width, a pair of doors arranged with each leaf to swing in a direction opposite from the other and with each door having a clear width of not less than 1.055 m is required as per ***Paragraph 19.2.2.5.4***
- In a psychiatric area, a horizontal exit serves a corridor 1.83 m or more in width, a pair of doors arranged with each leaf to swing in a direction opposite from the other and with each door having a clear width of not less than 0.81 m is required as per ***Paragraph 19.2.2.5.5***

The total egress capacity of the horizontal exit is not provided more than two-thirds of the total egress capacity of a given fire area and every fire area has provided at least one exit consisting of a door leading directly outside the building through an interior stair or a smokeproof enclosure or an exit passageway as per ***Paragraph 19.2.2.5.2*** and ***19.2.4.3***.

An approved vision panel is provided in each horizontal exit door and centre mullions are not positioned in horizontal exit door openings as per ***Paragraph 19.2.2.5.6***.

A2.6.7 Exit Discharge Requirements

The building has provided more than 50 percent of the required number of exits and more than 50 percent of the required egress capacity directly to outside to meet the 50 percent exit discharge requirement as specified in ***Section 11.7*** and ***Paragraph 27.2.7.2***.

The occupancies from the Hostel on floor 3 are able to egress from an enclosed stairway to an exterior door leading to a public way without exceeding 30 m travel distance allowance as specified in ***Paragraph 24.2.7.2*** and ***24.2.7.3***.

A2.6.8 Capacity of Means of Escape

A2.6.8.1 Exit Access Corridor, Aisles and Ramps

Aisles, corridors, and ramps in areas that are intended for the housing, treatment, or use of outpatients and for exit access in the building are more than 2.44 m in clear and unobstructed width as per ***Paragraph 19.2.3.3***. A clear width of more than 1.12 m is permitted in areas not for inpatient as per ***Paragraph 19.2.3.3(1)***. A clear width of more than 1.83 m is provided in psychiatric care hospital as per ***Paragraph 19.2.3.4***.

The corridor in Hostel on floor 3 is provided at least 1.12 m clear width as per ***Paragraph 24.2.3.3***. A clear width of more than 1.12 m is provided in Ambulatory Health Care Occupancies as per ***Paragraph 20.2.3.2***. The minimum width of access exit corridor in Assembly Occupancies is 1.12 m as per ***Paragraph 16.2.3.5***.

A2.6.8.2 Doors

As per ***Section 11.1.5*** and ***Section 11.2.1.2.3***, the minimum 2.03 m height and 0.81 m clear width door openings in means of egress have been achieved. All doors provided a clear opening of at least 0.81 m and shall not obstruct the required escape route width, unless one of the following conditions exists:

- For the total cumulative occupant load assigned to a particular stairway more than or equal to 2000 people, such stairway is required to be a minimum 1.42 m width in accordance with ***Paragraph 11.2.2.2.1.1 (B)*** and such door is required to be a minimum 0.94 m (two-thirds of the required width of the stairway) clear width as per ***Paragraph 11.2.1.2.3.2 (8)***. The building does not contain more than 2000 people and not require to meet the provision of ***Paragraph 11.2.1.2.3.2 (8)***.

As per ***Section 11.2.1.4.3***, all doors leaves in a means of egress have left more than one-half of the required width of a corridor when they swing and swung in the direction of egress travel. All doors have not projected more than 0.18 m into the required with of corridor or landing when fully open. All doors leaves open directly onto a stair with a landing.

The minimum clear width for doors in the means of egress from sleeping rooms and diagnostic and treatment areas (such as x-ray, surgery, or physical therapy) are 1.055 m as

per Paragraph 19.2.3.5. A clear width of 0.81 m is provided in psychiatric care hospital as per ***Paragraph 19.2.3.5(2)***.

Doors in exit stair enclosures, doors in non-Health Care Occupancies and doors serving newborn nurseries shall be not less than 0.81 m as per ***Paragraph 19.2.3.6***. Door widths in Emergency area are 0.81 m as per ***Paragraph 20.2.3.4***.

A2.6.8.3 Enclosed Stairway

The elevation of the floor surfaces on both sides of a door and thresholds at door openings are not exceed 13 mm. The stairway has landings at door openings and has maintained the same width along the direction of egress travel.

The minimum stairway width is 1.12 m because it serves an occupant load less than 2000 people but greater than 50 people as per ***Paragraph 11.2.2.2.1.1 (B)*** and ***Table 11.2.2.2.1.1(B)***. The landings and the stairway are having the same width in the direction of travel. They are not less than the width of the widest door leaf and are not less than the width of the stair. The stairway satisfies the requirements in ***Section 11.2.1.3***, ***Section 11.2.1.4.3*** and ***Section 11.2.2.3.2***.

A2.6.8.4 Exit Passageways

Paragraph 11.2.6.5.1 requires the width of an exit passageway shall be adequate to accommodate the required egress capacity of all exits that discharge through it. There are two exit passageways on floor 1 and serve occupants on that floor and upper floors. ***Paragraph 11.2.6.5.1(1)*** permits an exemption from the requirement that the occupants from upper floors be added to the required egress capacity and increased the width of the exit passageways.

The width of the exit passageways that serve as an exit stair discharges or as a horizontal transfer within an exit stair system are provided at least two-thirds of the width of the exit stair as per ***Paragraph 11.2.6.5.2(1)***. The building comply the requirements.

A2.6.8.5 Stairs

Dimensional criteria for stairs have been addressed using ***Table 11.2.2.2.1***. The minimum 1.12 m clear stair width, maximum 0.18 m and minimum 0.10 m height of risers, minimum

0.28 m tread depth, minimum 2.03 m headroom and maximum 3.66 m height between landings of the stairs have been achieved. The tread depth of the stair shall be not less than 0.33 m as per ***Paragraph 11.1.7.2.2***.

The tread depth and the riser height of the stairs are 0.3 m and 0.15 m respectively

A2.6.8.6 Width of Egress Routes

Egress capacity factors are related to the minimum clear width required for exits to ensure occupants can safely egress the building through the exits. Egress capacity factors are expressed in millimeter per person. Egress capacity factors for level egress components and stairways are different clear widths are determined from egress capacity factors and the maximum capacity for that particular egress element. The occupant load factor is based on ***Table 11.3.1.2*** and ***Table 11.3.3.1*** contains the capacity factors for egress elements.

For an area has more than one means of egress, the reminding egress capacity has at least 50 percent of the required egress capacity if one of the egress routes is blocked as per ***Paragraph 11.3.1.1.2***. All the staircases in the building serve more than one story and each staircase capacity is based on the portion of the story's occupant load assigned to that stair as per ***Paragraph 11.3.1.4***.

Assembly occupancies are located on ground floor (at the level of exit discharge). The main entrance and access to the main entrance has provided one-half of the total occupant load of such level as per ***Paragraph 16.2.3.3***. The main entrance or exit is located on ground level leading to the outside of the building to satisfy the requirement of ***Paragraph 16.2.3.3.3***.

Enclosed exit stair is not usable by those incapable of self-preservation and egress is permitted through an adjacent compartment. The capacity of means of escape is sufficient for the occupant load and is summarized in Table A2-7.

Table A2-7: Capacity of Means of Escape

Floor	Activity	Occupant Load for egress	Egress width (m) per Occupant		Required Exit Width (m)		Actual Exit Width (m)	
			Stair	Level	Stair	Level	Stair	Level
4	Whole floor	194	0.0076	0.005	1.47	0.97	4.48	3.24
3	Whole floor	119	0.0076	0.005	0.90	0.60	4.48	3.24
2	Whole floor	187	0.0076	0.005	1.42	0.93	4.48	3.24
1	Whole floor	717	0.0076	0.005	5.45	3.59	-	11.34
4	Exit 1	82	0.0076	0.005	0.62	0.41	1.12	0.81
	Exit 2	117	0.0076	0.005	0.89	0.59	1.12	0.81
	Exit 3	40	0.0076	0.005	0.58	0.38	1.12	0.81
	Exit 4	70	0.0076	0.005	0.55	0.36	1.12	0.81
3	Exit 1	42	0.0076	0.005	0.32	0.21	1.12	0.81
	Exit 2	98	0.0076	0.005	0.74	0.49	1.12	0.81
	Exit 3	77	0.0076	0.005	0.59	0.39	1.12	0.81
	Exit 4	77	0.0076	0.005	0.59	0.39	1.12	0.81
2	Exit 1	107	0.0076	0.005	0.81	0.54	1.12	0.81
	Exit 2	134	0.0076	0.005	1.02	0.67	1.12	0.81
	Exit 3	70	0.0076	0.005	0.53	0.35	1.12	0.81
	Exit 4	70	0.0076	0.005	0.53	0.35	1.12	0.81
1	Exit 1	36	0.0076	0.005	0.27	0.18	-	0.81
	Exit 2	49	0.0076	0.005	0.37	0.25	-	0.81
	Exit 3	18	0.0076	0.005	0.14	0.09	-	0.81
	Exit 4	36	0.0076	0.005	0.27	0.18	-	0.81
	Exit 5	166	0.0076	0.005	1.26	0.83	-	0.83
	Exit 6	61	0.0076	0.005	0.46	0.31	-	0.81
	Exit 7	30	0.0076	0.005	0.23	0.15	-	0.81
	Exit 8	11	0.0076	0.005	0.08	0.06	-	0.81
	Exit 9	19	0.0076	0.005	0.14	0.10	-	0.81
	Exit 10	29	0.0076	0.005	0.22	0.15	-	0.81
	Exit 11	29	0.0076	0.005	0.22	0.15	-	0.81
	Exit 12	100	0.0076	0.005	0.76	0.50	-	0.81
	Exit 13	100	0.0076	0.005	0.76	0.50	-	0.81
	Exit 14	34	0.0076	0.005	0.26	0.17	-	0.81

A2.6.9 Accessible Means of Egress

As per ***Paragraph 11.5.4.1***, the building requires not less than two accessible means of egress. According to the provision of ***Paragraph 24.2.2.12.2*** and ***28.2.2.12.2***, Hotels and Dormitories Occupancies and Business Occupancies are exempt from having to provide the two accessible rooms or spaces separated from each other by smoke resisting partitions. The building is protected with automatic sprinkler system and each space provides at least two means of egress routes to create the equivalent of two accessible means of egress.

Kitchen and cafeteria provide two accessible means of egress directly to outside.

Accessible means of egress is not required in Health Care Occupancies protected throughout by an approved, electrically supervised automatic sprinkler system as per ***Paragraph 11.5.4.1.3***.

A2.6.10Door Swing and Self-closing Devices

Stair enclosure and horizontal exit are normally not secured in the open position and equipped with self-closing or automatic closing device as per ***Paragraph 11.2.1.8***. The criteria for automatic closing are listed in ***Paragraph 11.2.1.8.2***.

Fire doors shall comply with the requirements of ***Section 8.7*** and shall be self-closing or automatic-closing as per ***Section 8.7.3***.

Paragraph 19.2.2.2.7 states that any door equipped with an automatic release device in an exit passageway, stairway enclosure, horizontal exit, smoke barrier, or hazardous area enclosure mentioned is permitted to be held open. The closing action of all such doors are arranged to initiate by an automatic sprinkler system and a fire alarm system as per ***Paragraph 19.2.2.2.7***. Furthermore, any initiation of a door-closing action in a stair enclosure must close the doors on the other levels of that stair enclosure in accordance with ***Paragraph 19.2.2.2.8***.

Section 19.3.6.3 required doors protecting corridor openings are constructed to resist the passage of smoke. Doors to toilet room, bathrooms, shower rooms, sink closets, and similar auxiliary spaces that do not contain flammable or combustible material are not required to be constructed to resist the passage of smoke. Door is not held open by devices other than those that release when the door is pushed or pulled. Door closing devices shall not be required on doors in corridor wall openings other than those serving required exits, smoke barriers, or enclosures of vertical openings and hazardous areas.

Doors in the required means of egress are required to be open in the direction of egress travel if there are more than 50 occupants using the door or if the door is used in an exit enclosure or if the door is used in a high hazard contents area as per ***Paragraph 11.2.1.4.2***.

A2.7 Interior Finish

Interior wall and ceiling finish material in all areas can be Class A or Class B or Class C because the building is sprinkler protected as per ***Section 16.3.3***, ***19.3.3***, ***27.3.3***, ***30.8.3.3*** and ***10.7***, except as indicated below:

- Exit enclosure in Hostel on floor 3 can be Class A or Class B only

Interior floor finish in all areas can be Class I or Class II or no critical radiant flux rating requirement (no classification required) because the building is sprinkler protected as per ***Section 16.3.3***, ***19.3.3***, ***27.3.3***, ***30.8.3.3*** and ***10.7***.

Detailed interior finish requirements are listed in Section 7.1 and 7.2.

A2.7.1 Interior Wall and Ceiling Finish

For the thickness of materials applied directly to the surface of walls and ceilings is less than 0.90 mm, the materials shall not be considered interior finish and shall be exempt from tests simulating actual installation if they are classified as Class A interior wall or ceiling finish.

Interior wall or ceiling finish shall be classified to be Class A, Class B or Class C based on test results from ASTM E 84, Standard Test Method of Surface Burning Characteristics of Building Materials, or UL 723, Standard for Test of Surface Burning Characteristics of Building Materials, or except as follows:

- Exposed portions of structural members is Type IV (2HH) construction
- Interior wall and ceiling finish tested in accordance with NFPA 286, Standard Methods of Fire Tests for Evaluating Contribution of Wall and Ceiling Interior

Finish to Room Fire Growth, and are complied with the criteria of ***Paragraph 10.3.6.2***, are classified as Class A in accordance with ASTM E 84 or UL 723

Interior wall and ceiling finishes for the building must be grouped in classes as shown in Table A1-7. Specific materials, trim and incidental finish shall satisfy the requirements in ***Section 10.4*** and ***Section 10.5***.

Table A2-8: Interior Wall and Ceiling Finishes Classification

Classification	Flame Spread Index (FSI)	Smoke Developed Index (SDI)
Class A	0 – 25	0 – 450
Class B	26 – 75	0 – 450
Class C	76 - 200	0 – 450

NOTES:

1. If the use of Class C interior wall and ceiling finish is required, Class A or Class B shall be permitted. If class B interior wall and ceiling finish is required, Class A shall be permitted, as per ***Paragraph 10.3.5***.
2. Interior wall and ceiling finish tested in accordance with NFPA 265, Standard Methods of Fire Tests for Evaluating Room Fire Growth Contribution of Textile Coverings on Full Height Panels and Walls, shall comply with the criteria of ***Paragraph 10.3.6.1***.
3. If an approved automatic sprinkler system is installed, Class C interior wall and ceiling finish materials shall be permitted in any location where Class B is required, and Class B interior wall and ceiling finish materials shall be permitted in any location where Class A is required, as per ***Paragraph 10.7.1***.
4. The flame spread of interior finish on walls and ceilings in exit enclosure shall be limited to Class A or Class B as per ***Paragraph 11.1.4.1***

A2.7.2 Interior Floor Finish

Interior floor finish such as carpet and carpetlike interior floor finishes shall comply with ASTM D 2859, Standard Test Method for Ignition Characteristics of Finished Textile Floor Covering Materials.

Interior floor finishes shall be classified to be Class I or Class II based on test results from NFPA 253, Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source, or ASTM E 648, Standard Test Method for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source.

Interior floor finishes for the building must be grouped in classes as shown in Table A1-8.

Table A2-9: Interior floor Finishes Classification

Classification	Critical Radiant Flux
Class I	≥ 0.45 W/cm^2
Class II	≥ 0.22 W/cm^2 and < 0.45 W/cm^2

NOTES:

3 Floor coverings, other than carpet, that are judged to represent an unusual hazard shall have a minimum critical radiant flux of 0.1 W/cm^2, as per ***Paragraph 10.6.2***.

4 If an approved automatic sprinkler system is installed, Class II interior floor finish materials shall be permitted in any location where Class I is required; and where Class II is required, no critical radiant flux rating shall be required, as per ***Paragraph 10.7.2***.

5 The flame spread of interior finish on floor in exit enclosure, including stair treads and risers, shall be less than Class II as per ***Paragraph 11.1.4.2***.

A2.8 Fire Fighting

A fire department access to the building is to meet the requirement of ***Section 7.1.5.2***. The vehicular access shall not be more than 15 m away from an exterior door that provides access to the building and that can be opened from outside as per ***Paragraph 7.1.5.2.2.1*** and an unavailable access road around the exterior of the building shall not be over 137 m as per ***Paragraph 7.1.5.2.3.2***. ***Paragraph 7.1.5.2.5.1*** and ***Paragraph 7.1.5.2.5.4*** state the vehicular access shall have at least 6.1 m unobstructed width, at least 4.1 m unobstructed height and a dead end vehicular access in excess of 46 m in length is not allowed. The building can achieve the requirements.

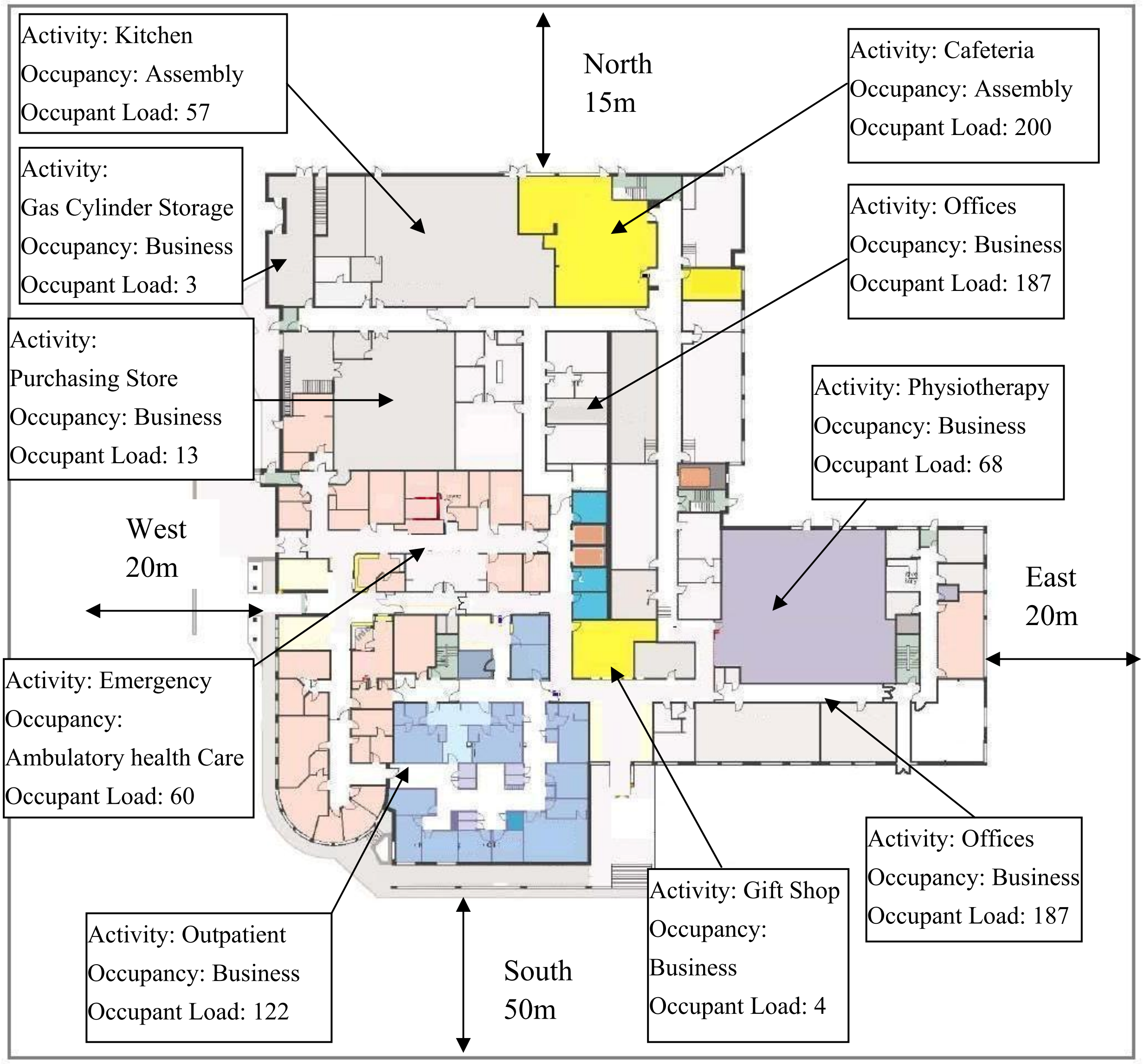


Figure A2-1: Building layout, relevant boundary, activity, occupancy type and occupant load on floor 1

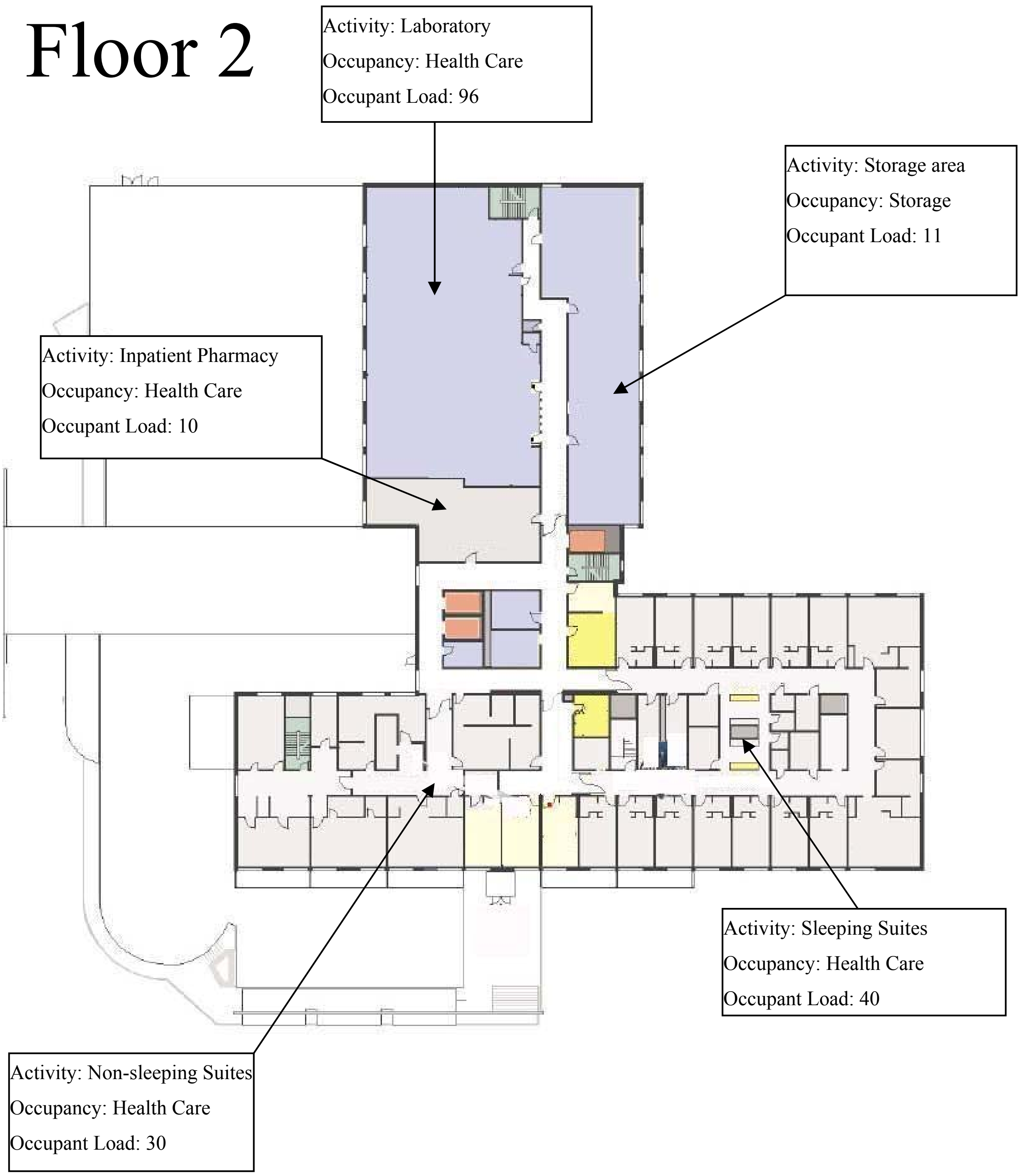


Figure A2-2: Activity, occupancy type and occupant load on floor 2

Floor 3

Figure A2-3: Activity, occupancy type and occupant load on floor 3

Floor 4

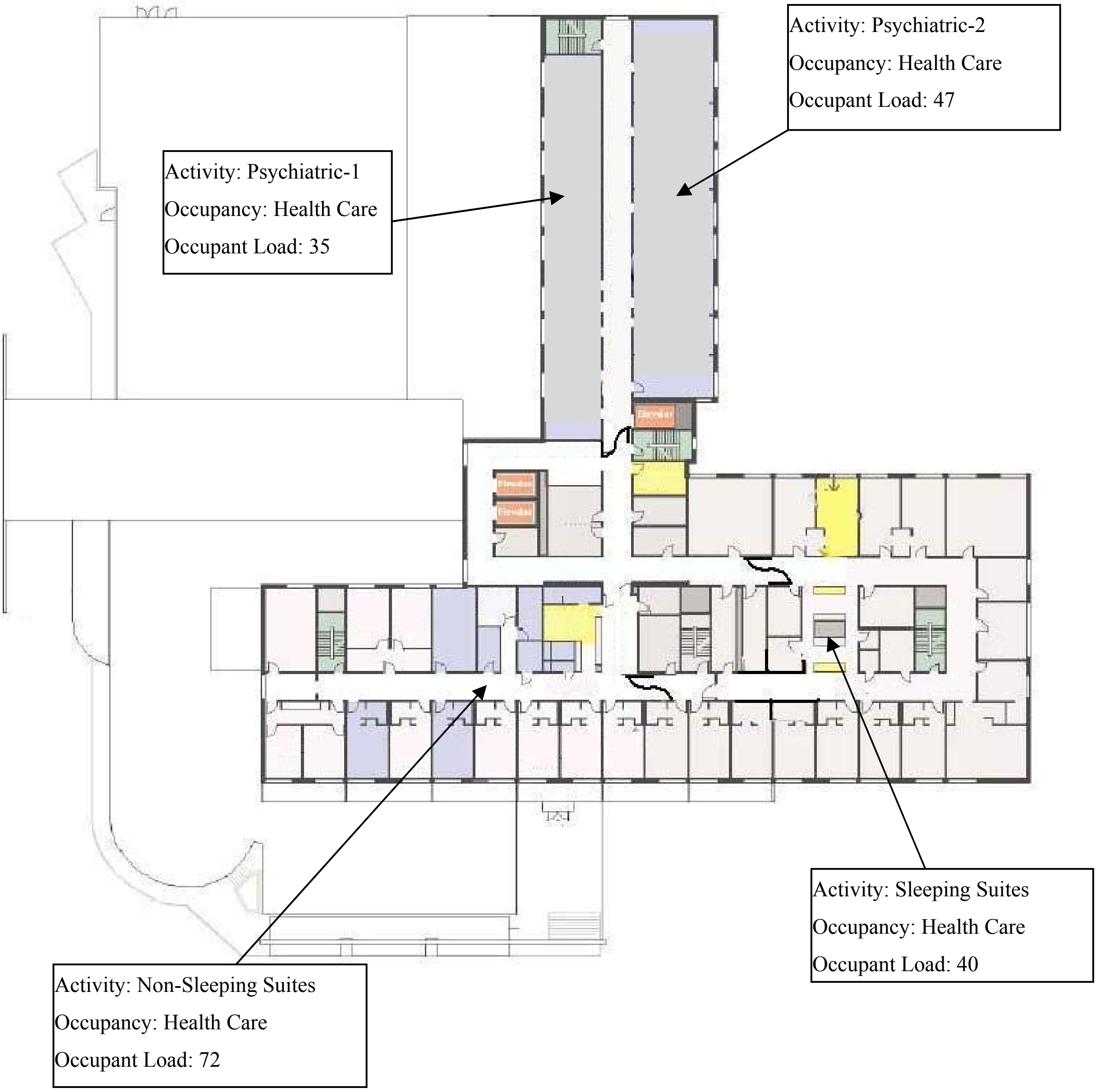


Figure A2-4: Activity, occupancy type and occupant load on floor 4

Floor 1

- Standard-response Sprinkler
- Horizontal Exit with 2-hrs Fire Resistance Rating
- Separated Occupancies with 1-hr Fire Resistance Rating
- Vertical Openings with Smoke Barrier & 2-hr Fire Barrier
- Exit Passageway with 2-hrs Fire Barrier
- Hazardous Area with 1-hr Fire Resistance Rating

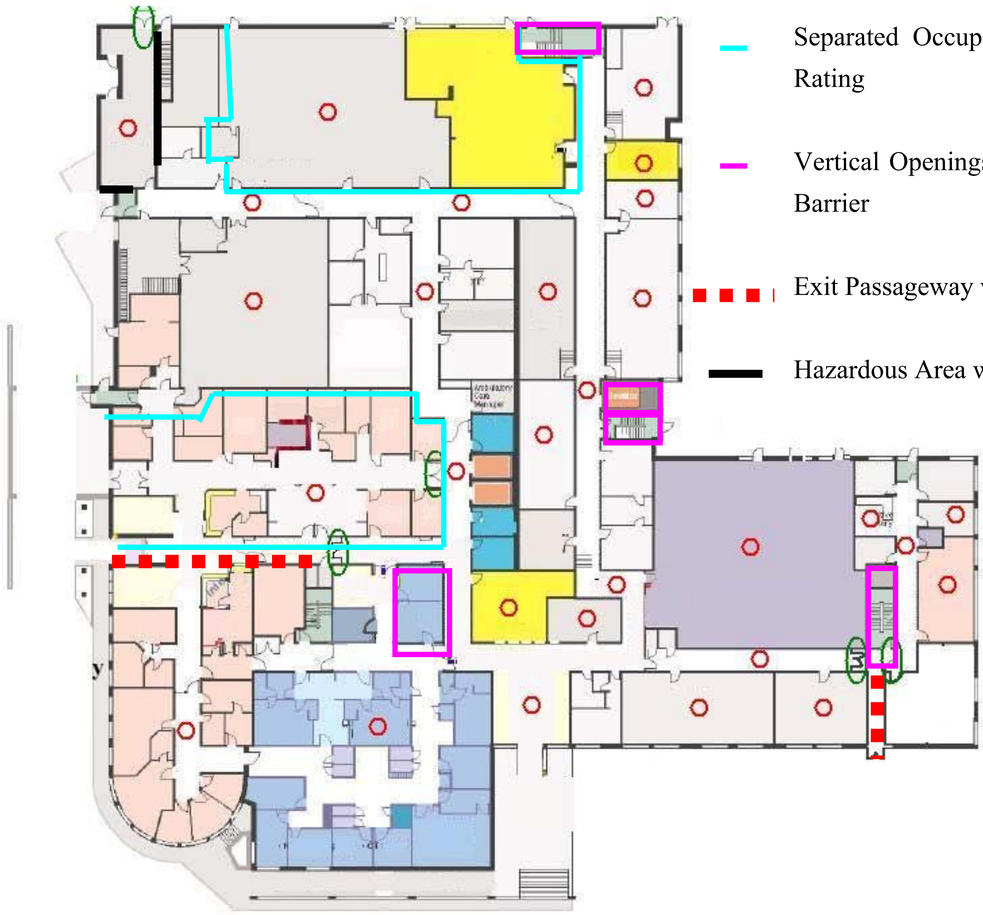


Figure A2-5: Required fire protection system on floor 1

Floor 2

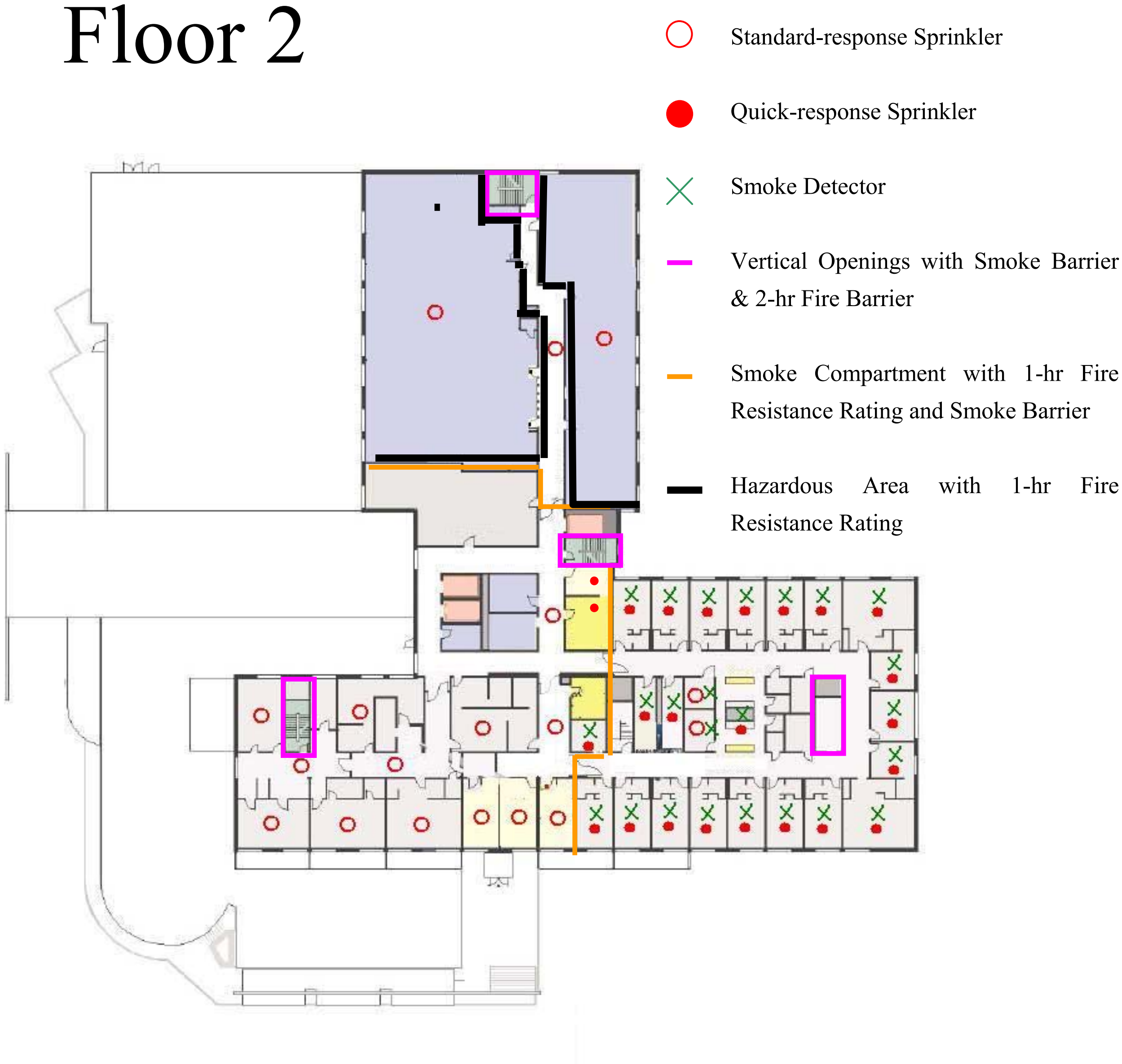
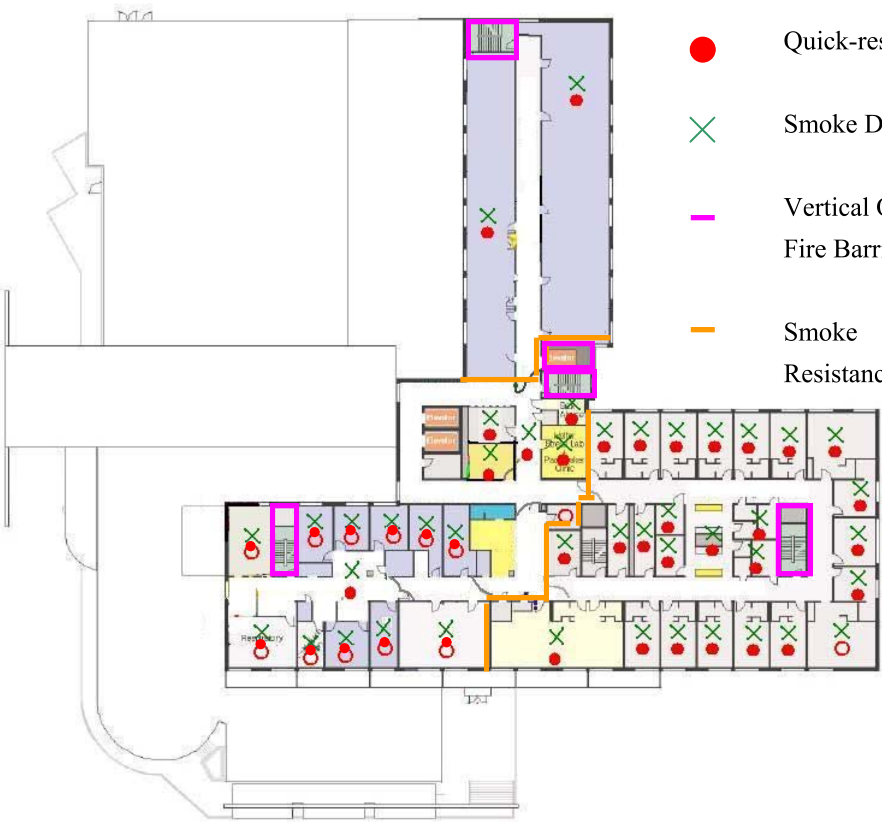


Figure A2-6: Required fire protection system on floor 2

Floor 3



○ Standard-response Sprinkler

● Quick-response Sprinkler

× Smoke Detector

— Vertical Openings with Smoke Barrier & 2-hr Fire Barrier

— Smoke Compartment with 1-hr Fire Resistance Rating and Smoke Barrier

Figure A2-7: Required fire protection system on floor 3

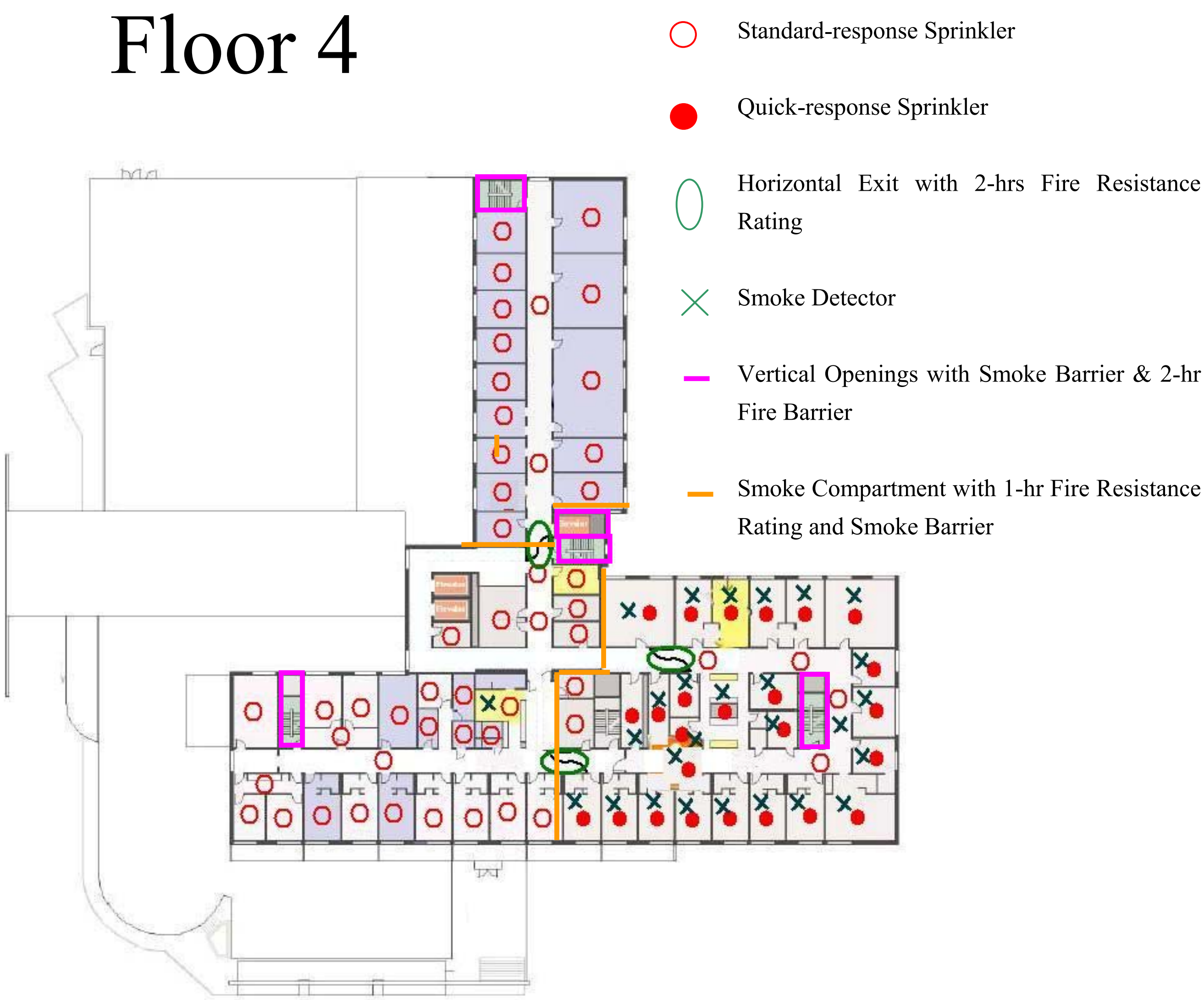


Figure A2-8: Required fire protection system on floor 4

Floor 1

Figure A2-9: Exits and egress routes on floor 1

Floor 2

Figure A2-10: Exits and egress routes on floor 2

Floor 4

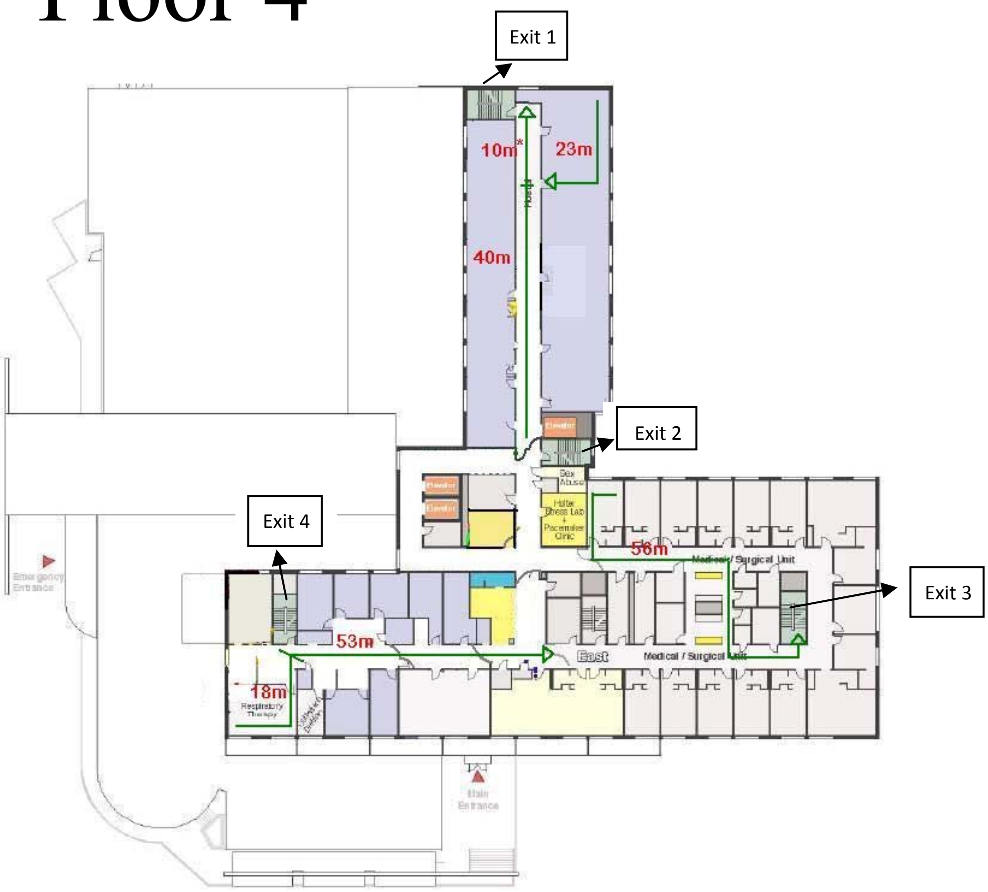


Figure A2-11: Exits and egress routes on floor 4

Appendix A3: Shopping Mall

A3.1 Introduction

The purpose of this appendix is to identify minimum requirements for the retail warehouse as mandated by NFPA 5000 Building Construction and Safety Code (the Code) and provides design suggestions to areas where the building cannot meet the provisions of the Code. The report summarises and identifies the minimum fire protection and life safety requirements contained in the code and standards applicable to the building. This report refers to ***Paragraph, Section*** and ***Table*** with the same numbering as the Code unless stated otherwise.

A3.2 Building Description

The building is a four storeys shopping mall containing a number of retail shops and visitors are easily to walk from shops to shops. Parking structures are located on every floor and each tenant space used for sales purposes is occupying on floor 2 and 3 only. Floor 4 contains parking structure and provides access to lower floors through escalators, stairways and lifts. Floor 2 and 3 contain retail spaces, food courts and restaurants and are connected by the central atrium. Floor 1 contains parking structure, storage areas and truck access. The building is 130 m wide, 211 m long and 14.4 m height and the activities within the building are summarised in Table 5-1.

Table A3-1: Description of Building

Floor	Activities	Detail
1	Roof parking structure	Ground floor
2	Retail tenancies, restaurant, food court and parking structure	Main entrance with access from street level
3	Retail tenancies, restaurant, food court and parking structure	Atrium connected to floor 2
4	Parking structure and storage areas	Roof level

Floor 2 and floor 3 have floor to floor height of 4.5 m and 2.4 m on floor 1. The atrium is 3.0 m extended above floor 4. Fuel dispensing devices are not contained in the building. The building layout is provided in Figure A3-1.

A3.2.1 Occupancy Classifications, Hazard Contents and Occupant Load

Section 6.1 classifies the overall building occupancy as a Mercantile Occupancy. The shopping mall is classified as a mall building as per ***Paragraph 27.4.4.2.2*** because the building contains a number of occupancies and tenants. All tenant spaces having an aggregate gross area of more than 2800 m^2 for sales purposes are classified as Class A, all tenant spaces having an aggregate gross area of more than 280 m^2 but not more than 2800 m^2 for sales purposes are classified as Class B, and all tenant spaces having an aggregate gross area of not more than 280 m^2 for sales purposes are classified as Class C.

The shopping mall contains two Class A Mercantile Occupancies, twenty Class B Mercantile Occupancies and twenty Class C Mercantile Occupancies. The tenant spaces in the shopping mall are classified individually as per ***Paragraph 27.1.3.2.4(4)***.

A3.2.1.1Multiple Occupancies

The primary use of the building is for display and sale of merchandise and ***Section 6.1*** classifies the overall building occupancy as a Mercantile Occupancy. The building contains criteria for classifying spaces as other occupancies. The building contains multiple occupancies and they can be protected either as mixed occupancies or as separated occupancies as per ***Paragraph 6.2.1.1***.

The restaurant with cooking facilities and the food court are classified as assemble occupancy because the area is gathering 50 or more people for eating, drinking and entertainment as per Paragraph 6.1.2.

The storage area on Floor 1 is intended for sheltering of merchandise and is classified as storage occupancy as per ***Paragraph 6.1.13.1***.

The car parks located in several places in the building is classified as storage occupancy as per ***Paragraph 6.1.13.1***.

A3.2.1.2 Separated Occupancies

The other occupancies are required to be separated from the Mercantile Occupancies by construction having a minimum 2 hours fire resistance rating (vertically and horizontal aligned).

Parking structures are Storage Occupancies and they are protected as separated occupancies. ***Paragraph 6.2.1.2*** states that egress routes from occupancy to involve traverse through doors in the separating construction into the other occupancy is not permitted in separated occupancy. The required means of egress from occupancy are provided by independent exits.

There are two restaurants located in the building and are protected as separated occupancies but they are not required to be separated from the building as per ***Paragraph 27.4.4.4***.

Each restaurant provides required means of egress to the building. Egress from Assembly Occupancies to Mercantile Occupancies is permitted and it is not in violation of the requirement of ***Paragraph 6.2.1.2***.

A3.2.1.3 Mixed Occupancies

The other occupancies are not required to be separated from the Mercantile Occupancies by construction having a minimum 2 hours fire resistance rating. The most restrictive life safety requirements applicable to any one occupancy present would be required for all the occupancies.

The building does not contain any multiple occupancies protected as mixed Occupancies.

A3.2.1.4 Occupant Load Factors

Occupant load factors are expressed in terms of square meters per person. The Code uses occupant load factors to determine the allowable number of occupants in a given area and also allows the occupant load to be increased above the calculated number provided the other egress provisions are met and the occupant load does not exceed 0.46 m^2/person. The occupant load is calculated from relevant occupant load factors taken from ***Table 11.3.1.2*** and ***Figure 11.3.1.2***.

The classification of Hazard of Contents for the building has been taken from ***Section 6.3.2***. The occupancy classification, fire hazard classification, area and occupant load are detailed in Table A3-2. The overall activity, occupancy type and occupant load are included in Figure A3-2 to Figure A3-5.

Table A3-2: Classification of Occupancy, Hazard of Contents and Occupant Load

Floor	Activity	Occupancy	Fire Hazard	Occupant Density (m^2 per person)	Gross Area (m^2)	Occupant Load for Egress (persons)
4	Car park	Storage	Ordinary	46.5	21699	467
				Floor 4 total		**467**
3	Restaurant	Assembly	Ordinary	Fixed Seats	320	200
	Retail spaces	Mercantile	Ordinary	2.8	9338	3335
	Anchor Building – 3	Mercantile	Ordinary	5.6	2603	465
	Anchor Building - 4	Mercantile	Ordinary	5.6	2603	465
	Food Court	Assembly	Ordinary	Fixed Seats	100	50
	Car park	Storage	Ordinary	46.5	2496	54
				Floor 3 total		**4569**
2	Restaurant	Assembly	Ordinary	Fixed Seats	320	200
	Retail spaces	Mercantile	Ordinary	2.8	9917	3335
	Anchor Building	Mercantile	Ordinary	2.8	2603	930
	Anchor Building	Mercantile	Ordinary	2.8	2603	930
	Food Court	Assembly	Ordinary	Fixed Seats	100	50
	Car park	Storage	Ordinary	46.5	2496	54
				Floor 2 total		**5499**
1	Car park	Storage	Ordinary	46.5	16710	360
	Storage	Storage	Ordinary	46.5	2185	47
				Floor 1 total		407
				Building Total		**10942**

A3.2.2 Mezzanines

Floor 3 is located between the floor 2 and the ceiling of a space and it is considered a story but not a mezzanine because the floor area exceeds one-third the open area of the space as per ***Paragraph 8.13***. Therefore, floor 3 is included as a story for the purpose of determining the allowable number of stories in the building.

Walls on floor 3 that open to the space are 1.065 m high served as guards to prevent falls over the open side of the floor to meet the openness requirement as specified in ***Paragraph 8.13.3.1*** but still meet the minimum height of guards requirements as specified in ***Paragraph 11.2.2.4.6***.

A3.2.4 Communicating Space

Communicating space is located in the middle of the shopping mall and it is connecting floor 2 and floor 3. The space is permitted in the shopping mall and all the protection provisions of ***Paragraph 8.12.2(1)*** through ***(8)*** are met.

The building has a floor opening connecting one story only (between floor 2 and floor 3) and a smoke control system is not required as per ***Paragraph 27.4.4.8***.

A3.2.5 Anchor Buildings

Two Class A Mercantile Occupancies are located on the west side of the building, contain ordinary hazard contents, have direct access to the building and have all required means of egress independent of the building. They are considered as anchor building as per ***Paragraph 27.4.4.2.1***.

A3.2.6 Closed or Open Type Parking Structures

Parking structures from floor 1 to floor 4 are defined as open type parking structures as per the ***Paragraph 3.3.607.9*** because the openings are distributed over 40 percent of the parking structures perimeter.

Parking structures are used only for the storage of vehicles and are classified as ordinary hazard as per ***Paragraph 30.8.1.5***.

A3.2.7 Bulk Merchandising Retail Buildings

The building does not contain or allow any area for bulk merchandising retail purpose because the ceiling height measured from the floor to the ceiling is less than 4.875 m as per ***Paragraph 27.4.5.1***.

A3.2.8 High Rise Building

The floor height measured from the lowest level of fire department vehicle access to the highest floor of an occupied story is not greater than 23 m. The building is not considered as a high rise building as defined in ***Paragraph 3.3.64.10***.

A3.3 Construction

A3.3.1 Type of Construction

The external constructions are concrete walls and the internal constructions are gypsum boards. Buildings and structures shall be classified according to their type of construction as per ***Paragraph 7.2.1.1***. NFPA 220, Standard on Types of Building Construction, shall be used to determine the requirements for the construction classification. Concrete wall and gypsum are classified as Type II construction because they are non-combustible or limited combustible material as per ***Paragraph 7.2.3.1***. The construction of the building is Type II construction.

The north wall of the building is 30m from the property line, 20 m to the East, 15 m to the South and 25 m to the West. All exterior walls are not required to have a fire resistance rating as per ***Table 7.3.2.1***. For a separation distance between the building and the property line of less than or equal to 3 m, exterior walls are required to have a fire resistance rating.

A3.3.2 Allowable Building Height and Area

The shopping mall is a four stories building. The height of the building is 14.4 m and the largest area per story is 22292 m^2. The building is constructed with Type II (222) and has achieved the height and area requirements as per ***Table 7.4.1***. The table establishes building construction type limitations based on the total number of stories in a building and stories in height. It is applied to Mercantile Occupancies by starting the story count with the level of exit discharge and ending with the highest occupiable story, even if that story is not used as a Mercantile Occupancies.

The code regulates the height and area of buildings based on occupancy of the building and construction type. ***Table 7.4.1*** has no limitation on the area of the Mercantile Occupancies of Type II (222) construction but limits the number of stories and building height to 12 stories and 54.8 m.

The building is classified as a four story building and has 22292 m^2 floor area. The building achieved the allowable height and area requirements. The allowable height and area are summarised in Table A3-3.

Table A3-3: Allowable Height and Area

	Actual	Allowable (*Table 7.4.1*)	Increase for Sprinklers (*Table 7.4.1*)
Mercantile Occupancies: Type of Construction: Type II (222)			
Building Height (m)	14.4	48.7	54.8
Building Height (Stories)	4	11	12
Building Area (m^2)	22292	Unlimited	Unlimited
Assembly Occupancies (<300): Type of Construction: Type II (222)			
Building Height (m)	14.4	48.7	54.8
Building Height (Stories)	4	11	12
Building Area (m^2)	420	Unlimited	Unlimited
Storage Occupancies: Type of Construction: Type II (222)			
Building Height (m)	14.4	48.7	54.8
Building Height (Stories)	4	11	12
Building Area (m^2)	18720	Unlimited	Unlimited

A3.4 Life Safety System Requirements

A3.4.1 Automatic Sprinkler System

A combination of factors including occupancy, building area, construction type, building height, location relative to exit discharge and occupant load trigger sprinkler protection for buildings. Several exceptions are allowed but none of the exceptions are relevant to the building.

The code mandates mall building, anchor buildings and parking structures to be protected by an approved, supervised automatic sprinkler system in accordance with NFPA13 and ***Paragraph 55.3.2***. ***Paragraph 27.4.4.7.1*** and ***30.8.3.5*** requires automatic sprinkler system protection for the building.

A3.5 Fire Protection Requirements

A3.5.1 Internal Spread of Fire and Smoke

A3.5.1.1 Parking Structures

Parking structures are attached to multi-story shopping mall and provide access through doors, stairs or elevators to the mercantile occupancy. The provision of ***Paragraph 27.1.2.2.1*** requires a fire barrier having a fire resistance rating of not less than 2 hours to separate the mercantile occupancy and the parking structures. The building is protected throughout by an approved, supervised automatic sprinkler system in according with NFPA 13, ***Paragraph 55.3.2*** and ***Paragraph 27.4.4.7.1***, and openings in the fire barrier are met the conditions specified in ***Paragraph 27.1.2.2.2***. Therefore, the openings are not required to be fire rated but are required to be smoke partitions in accordance with ***Section 8.10***.

A3.5.1.2 Anchor Building Separations

Each anchor building is separated form the building and other anchor buildings by a fire barrier having 2-hour fire resistance rating as per ***Paragraph 27.4.4.3.2.1***. Openings between an anchor building and the pedestrian area of the building are permitted to be unprotected as per ***Paragraph 27.4.4.3.3*** because each anchor building does not contain any bulk merchandising retail building.

A3.5.1.3 Vertical Openings

Section 8.12 states that enclosures connecting three stories or less shall provide at least one hour fire barrier and construct as a smoke barrier to restrict the passage of smoke. For enclosures connecting four stories or more shall provide at least two hours fire barrier. Elevators and enclosed stairways are provided the above criteria.

Referring to section 2.2 of this appendix, there is an open stairway between floor 3 and floor 2, and between floor 2 and floor 1.

Unprotected vertical openings are permitted between the street floor and the first street floor above as per **Paragraph 27.3.1(1)(b)**. Smoke barrier and fire resistance rating for the open stairway that provides access from floor 2 to floor 3 are not required. Note that floor 2 is classified as a street floor in accordance with ***Paragraph 27.2.1.4*** and ***3.3.253.2*** because floor 2 is also used as an entrance from a principal street.

Smoke barrier and fire resistance rating for the open stairway between floor 2 and floor 1 is not required and it is not required to be enclosed because floor 1 is located below the street floor as per **Paragraph 27.3.1(1)(b)**.

Ramps are not required to be enclosed in the sprinklered open or closed parking structure as per ***Paragraph 30.8.3.1.1.5***.

A3.5.1.4 Vertical Exit Enclosures

Vertical exit enclosures such as interior exit stairways shall be enclosed with fire barriers. Exit enclosures shall have a fire resistance rating not less than one hour where connecting less than four stories and not less than two hour where connecting four stories or more as per ***Section 11.1.3.2***.

Occupants are able to travel from upper floors to ground floor through an enclosed stairway and access directly to outside. The enclosed stairways are required to achieve at least two hour fire resistance rating as per ***Paragraph 11.1.3.2.1.1***. The enclosed stairway acts as a vertical shaft, 2 hour fire resistance rating is required for walls and 1.5 hour fire resistance rating is required for fire door assemblies as per ***Table 8.7.2***.

A3.5.1.5 Corridors

Although ***Paragraph 11.1.3.1*** states that corridor used as exit access and serving more than 30 occupants are required to be separated from other parts of the building by walls having at least one hour fire resistance rating, but it is not required any fire resistance rating because the building is protected by an approved automatic sprinkler system as per ***Paragraph 27.3.6.1***.

A3.5.1.6 Horizontal Exits

Horizontal exits separating building or areas shall provide at least 2-hour fire resistance rating as per ***Paragraph 11.2.4.3.1***.

A3.5.1.7 Miscellaneous Requirements

At least one hour fire resistance rating is required between tenant spaces, and no fire resistance rating is required between the tenant space and the shopping mall as per ***Paragraph 27.4.4.3.5***.

Paragraph 27.4.4.4 exempts the requirement of providing complete separation between assembly occupancy and mercantile occupancy in the shopping mall. The food court located on floor one does not require any separation.

The storage area in the building does not require any special hazard protection in ***Section 8.15*** because an automatic sprinkler system is installed throughout the building as per ***Paragraph 27.3.2.1.2***.

The overall interior passive fire protection requirements are given in Figure A3-6 to Figure A3-9.

A3.5.2 External Spread of Fire and Smoke

The minimum fire resistance ratings for Type II (222) construction are given in ***Table 7.2.1.1*** and ***Table 7.3.2.1***, whichever is greater as per ***Paragraph 7.3.2.1***.

Paragraph 7.3.9 specified the requirements for vertical separation of exterior openings. The building does not require vertical separation of exterior openings as per ***Paragraph 37.1.4.1***.

Allowable area of unprotected openings for the North, East and South walls have not been exceeded that permitted by ***Table 7.3.5(b)*** because they are not required to have a fire resistance rating as determined by ***Table 7.3.2.1*** as per ***Paragraph 7.3.5***. The West wall needs to be fire rated for two hours and there is no allowable area of unprotected openings to be tested by ***Table 7.3.5(b)***. ***Paragraph 7.3.5*** is complied. The applicable data is summarised in

Table A1-3 and Table A3-5, and the distance to the relevant boundary is shown in Figure A3-1. The overall exterior passive fire protection requirements are given in Figure A3-6 to Figure A3-9.

Table A3-4: Fire Resistance Rating Requirements for Exterior Walls on Fire Separation Distance

Location	Enclosing Rectangle H x W (m)	Distance to the Relevant Boundary (m)	Fire Resistance Rating (hr)	Percentage of Unprotected Areas	
				Allowed[1] (%)	Actual (%)
North Wall	182 x 14.4	30	2	100	20 - OK
East Wall	82 x 7.5	20	2	100	20 - OK
South Wall	77 x 7.5	15	2	100	20 - OK
West Wall	49 x 7.5	25	2	100	20 - OK

Note 1: The allowable unprotected areas of the external walls have been addressed using ***Table 7.3.5(b)*** and are permitted to be doubled as per ***Paragraph 7.3.5.5.1***.

Table A3-5: Fire Resistance Rating Requirements for Building Elements

Building Element	Fire Separation Distance (m)	Required Rating (Hours)	Detail
Bearing Walls			
Exterior			
North	30	0	***Table 7.2.1.1*** and ***7.3.2.1***
East	20	0	
South	15	0	
West	25	0	
Interior	-	0	***Table 7.2.1.1***
Non Bearing Walls and Partitions			
Exterior			
North	30	0	***Table 7.2.1.1***
East	20	0	
South	15	0	
West	25	0	
Interior	-	0	
Floor Construction	-	2	***Table 7.2.1.1***
Roof construction	-	1	***Table 7.2.1.1***
Columns, Beans, Girders, Trusses and Arches	-	2	***Table 7.2.1.1***
Occupant Separation	-	2	Storage Occupancies, Mercantile Occupancies and Anchor Buildings
Corridor Separation	-	0	***Paragraph 27.4.4.3.5***

Fire Wall Separation	-	2	Exit passageway
Vertical openings	-	2	Elevators and enclosed stairways
		0	Open stairways between floor 1 and floor 2, and between floor 2 and floor 3
Tenant Separation		1	***Paragraph 27.4.4.3.5***
Smoke Barrier Separation	-	2	Elevators and enclosed stairways
Horizontal exit	-	2	Exit passageways
Shafts for exit	-	2	Enclosed stairways
Shafts for other	-	2	Elevators

A3.6 Means of Escape

A3.6.1 Exits

The minimum number of exits is generally based on ***Section 11.4.1***. All rooms and spaces within each story shall be provided with and have access to the minimum number of exits as follows (refer to Figure A3-13 to Figure A3-16 for the location of exits):

- Under 500 occupants requires a minimum of two exits
- 500 occupants to 1000 occupants requires a minimum three exits
- Over 1000 occupants requires a minimum four exits

Each floor provides at least two separate exits and occupants are able to enter an enclosed exit stair on that floor without travelling to another floor to reach the entrances to the exits. The building has met the minimum number of exits requirements in accordance with ***Paragraph 27.2.4.1***.

A3.6.2 Single Means of Egress Requirements

Single means of egress in all retail areas of less than 280 m^2 is allowed provided the travel distance to the exit or to the building is not exceeding 30 m and the building is sprinklered as per the requirements of ***Paragraph 27.4.4.5.5.2***.

Single means of egress is permitted from any story in Storage Occupancies as per

Paragraph 30.2.4.1(2), provided that the exit can be reach in 30 m. However, none of the area in the building is relevant to the requirement.

A3.6.3 Length of Escape Routes

A3.6.3.1 Mercantile Occupancies

A3.6.3.1.1 Dead-ends Corridors

Paragraph 27.2.5.2 states that dead-end corridors shall not exceed 15 m for sprinklered building. Each area in the building provides at least two means of egress. Neither of them is associated with corridors and no other dead ends existed.

A3.6.3.1.2 Common Path Travel

Paragraph 27.2.5.3 limits the common path of travel to 15 m or less for sprinklered building. Common path of travel is the portion of the means of egress that must be traversed until such a point that at least two independent means of egress to at least two exits are available. The building complied with the common path of travel provisions.

Exit access travel is permitted to be common for the distances permitted as common paths of travel as per ***Paragraph 27.4.4.5.5.1***.

A3.6.3.1.3 Travel Distance

Paragraph 27.2.6 requires the maximum travel distance measured from the most remote place in the building to an exit not exceed 76 m for sprinklered building. The travel distance in the building is less than or equal to 76 m.

A3.6.3.2 Assembly Occupancies

A3.6.3.2.1 Dead-ends Corridors

Paragraph 16.2.5.1.2 states that dead-end corridors shall not exceed 6.1 m for sprinklered building. Each area in the building provides at least two means of egress. Neither of them is associated with corridors and no other dead ends existed.

A3.6.3.2.2 Common Path Travel

Paragraph 16.2.5.1.3 limits the common path of travel to 6.1 m or less for sprinklered building. Common path of travel is the portion of the means of egress that must be traversed until such a point that at least two independent means of egress to at least two exits are available. The building complied with the common path of travel provisions.

A3.6.3.2.3 Travel distance

Paragraph 16.2.6.2 requires the maximum travel distance measured between any point in a room and an exit is not exceeding 61 m for sprinklered building. The travel distance in the Assembly Occupancies are less than or equal to 61 m. Travel through kitchen, store room or hazardous areas are not permitted as per ***Paragraph 16.2.5.2***.

A3.6.3.3 Storage Occupancies

A3.6.3.3.1 Dead-ends Corridors

Paragraph 30.8.2.5.2 states that dead-end corridors shall not exceed 15 m for sprinklered parking structure and not exceed 30 m for sprinklered storage area as per ***Paragraph 30.2.5***. Each area in the building provides at least two means of egress. Neither of them is associated with corridors and no other dead ends existed.

A3.6.3.3.2 Common Path of Travel

Paragraph 30.8.2.5.1 limits the common path of travel to 15 m or less for sprinklered parking structure and the common path of travel in the storage area is not exceeding 30 m as per ***Paragraph 30.2.5***. Common path of travel is the portion of the means of egress that must be traversed until such a point that at least two independent means of egress to at least two exits are available. The building complied with the common path of travel provisions.

A3.6.3.3.3 Travel Distance

Paragraph 30.8.2.6 requires the maximum travel distance measured between any point in a room and exits are not exceeding 61 m for sprinklered enclosed parking structure and 122 m for sprinklered open parking structure. The maximum travel distance is limited to 122 m for sprinklered storage area as per ***Paragraph 30.2.6***. The travel distance in the Storage Occupancies complied with the travel distance provision.

The maximum escape route lengths are as shown below in Table A3-6. Travel direction and travel distance are detailed in FigureA3-10 to FigureA3-13.

If there are two exits, the maximum travel distance in Storage Occupancy, Mercantile Occupancy and Assembly Occupancy is measured from the most remote point in a room to the nearest exit.

Table A3-6: Length of Escape Routes

Area	Occupancy	Dead End Corridor (m)		Common Path (m)		Travel Distance (m)	
		Allowed[1]	Actual	Allowed[1]	Actual	Allowed[1,3]	Actual[2]
Open Parking structures	Storage	15	0	15	0	122	112
Retail Areas	Mercantile	15	0	30	0	137	125
Anchor Buildings	Mercantile	15	0	30	0	76	65
Restaurants	Assembly	6.1	0	6.1	0	61	25
Storage areas	Storage	30	0	30	0	122	110

Note 1: Approved and supervised automatic sprinkler system is installed throughout the building in accordance with NFPA 13 and ***Paragraph 55.3.2***.

Note 2: On entering a protected stairs or exit the occupants are considered to have ended their travel distance

Note 3: An extra 61 m travel distance is permitted because the shopping mall has met the provision of ***Paragraph 27.4.4.5.2.2*** and they are listed as follow:

- At least 6.1 m clear width to accommodate egress requirements
- At least 3.05 m clear and unobstructed space for exit access
- At least 1.675 m wide exit access leading directly to an exit
- The building including anchor buildings, except open parking structures on floor 4, are protected throughout by an approved, supervised automatic sprinkler system
- Tenant spaces are separated from each other with fire resistance rating walls and no separation is required between a tenant space and the building

A3.6.4 Arrangement of Means of Egress

As per ***Paragraph 11.5.1.2*** corridors are provided at least two approved exits and are provided exit access without passing through any intervening rooms. The building is complied with the Paragraphs.

Access to an exit shall not pass through kitchens; restroom; closets; bedrooms or similar spaces; or other rooms or spaces subject to locking as per ***Paragraph 11.5.2***. Several exceptions are allowed but none of the exceptions are relevant to the building.

The building is equipped throughout with an automatic sprinkler system. ***Section 11.5.1.4*** requires the exits to be separated by at least one-third of the length of the maximum overall diagonal dimension of the building area served, measured in a straight line between the nearest edge of the exits. The building meets the requirement.

A3.6.5 Inside open stairways

Inside open stairways in the atrium are permitted to serve as a component of the required means of egress system between floor 3 and floor 2 for this building as per ***Paragraph 27.2.1.2*** because the stairways are connected to one floor only. The inside open stairways between floor 1 and floor 2 is not permitted to serve as a component of the required means of egress system. Floor 2 is classified as a street floor in accordance with ***Paragraph 27.2.1.4*** and ***3.3.253.2*** because floor 2 is also used as an entrance from a principal street.

A3.6.6 Ramp-type Open Parking Structure

Ramps in the parking structures are not permitted to serves as a component of means of egress because they are not satisfied the requirements of ***Paragraph 30.8.2.2.6.1***.

A3.6.7 Anchor Buildings

All anchor buildings have means of egress independent of the building and required egress from an anchor building is not permitted to pass through the building.

A3.6.8 Horizontal Exits

The total egress capacity of the horizontal exit is not provided more than half of the total egress capacity of a given fire area as per ***Paragraph 11.2.4.1.2***.

A3.6.9 Escalators and Moving Walks

Escalators and moving walks are prohibited to be the required means of egress as per ***Paragraph 11.2.7***.

A3.6.10 Exit Discharge Requirements

The building has provided more than 50 percent of the required number of exits and more than 50 percent of the required egress capacity directly to outside to meet the 50 percent exit discharge requirement as specified in ***Section 11.7*** and ***Paragraph 27.2.7.2***.

A3.6.11 Capacity of Means of Escape

A3.6.11.1 Exit Access Corridor

The minimum width of exit access corridor is 1.675 m as per ***Paragraph 27.4.4.5.2.2***.

A3.6.11.2 Doors

As per ***Section 11.1.5*** and ***Section 11.2.1.2.3***, the minimum 2.03 m height and 0.81 m clear width door openings in means of egress have been achieved. All doors provided a clear opening of at least 0.81 m and shall not obstruct the required escape route width, unless one of the following conditions exists:

- For the total cumulative occupant load assigned to a particular stairway more than or equal to 2000 people, such stairway is required to be a minimum 1.42 m width in accordance with ***Paragraph 11.2.2.2.1.1 (B)*** and such door is required to be a minimum 0.94 m (two-thirds of the required width of the stairway) clear width as per ***Paragraph 11.2.1.2.3.2 (8)***.

None of the stairways in the building contains more than 2000 people and they are not required to meet the provision of ***Paragraph 11.2.1.2.3.2 (8)***.

As per ***Section 11.2.1.4.3***, all doors leaves in a means of egress have left more than one-half of the required width of a corridor when they swing and swung in the direction of egress travel. All doors have not projected more than 0.18 m into the required with of corridor or landing when fully open. All doors leaves open directly onto a stair with a landing.

A3.6.11.3 Stairways

The elevation of the floor surfaces on both sides of a door and thresholds at door openings are not exceed 13 mm. The stairway has landings at door openings and has maintained the same width along the direction of egress travel.

The minimum stairway width is 1.12 m because it serves an occupant load less than 2000 people but greater than 50 people as per ***Paragraph 11.2.2.2.1.1 (B)*** and ***Table 11.2.2.2.1.1(B)***. The landings and the stairway are having the same width in the direction of travel. They are not less than the width of the widest door leaf and are not less than the width of the stair. The stairway satisfies the requirements in ***Section 11.2.1.3***, ***Section 11.2.1.4.3*** and ***Section 11.2.2.3.2***.

A3.6.11.4 Exit Passageways

Paragraph 11.2.6.5.1 requires the width of an exit passageway shall be adequate to accommodate the required egress capacity of all exits that discharge through it. There is an exit passageway on floor 1 that serves occupants from upper floors to a public way.

The width of the exit passageways that serve as an exit stair discharges or as a horizontal transfer within an exit stair system are provided at least two-thirds of the width of the exit stair as per ***Paragraph 11.2.6.5.2(1)***.

Paragraph 11.2.6.5.1(1) permits an exemption from the requirement that the occupants from upper floors be added to the required egress capacity and increased the width of the exit passageways. ***Paragraph 27.2.3.2*** requires street floor has sufficient egress capacity for the occupant load of the street floor plus the occupant load from upper floor discharging through the street floor in Class A and Class B Mercantile Occupancies. However, the building is classified as mall buildings according to the definition of ***Paragraph 27.4.4.2.2***. The requirement from ***Paragraph 27.2.3.2*** is exempted.

A3.6.11.5 Stairs

Dimensional criteria for stairs have been addressed using ***Table 11.2.2.2.1***. The minimum 1.12 m clear stair width, maximum 0.18 m and minimum 0.10 m height of risers, minimum 0.28 m tread depth, minimum 2.03 m headroom and maximum 3.66 m height between landings of the stairs have been achieved. The tread depth of the stair shall be not less than 0.33 m as per ***Paragraph 11.1.7.2.2***.

The tread depth and the riser height of the stairs are 0.3 m and 0.15 m respectively

A3.6.11.6 Width of Egress Routes

Egress capacity factors are related to the minimum clear width required for exits to ensure occupants can safely egress the building through the exits. Egress capacity factors are expressed in millimeter per person. The egress capacity factors for level egress components and stairways are different. Clear widths are determined from egress capacity factors and the maximum capacity for that particular egress element. The occupant load factor for the mall building is based on the gross leasable area in accordance with ***Figure 11.3.1.2*** and the occupant load factor for the rest of the building are based on ***Table 11.3.1.2***. ***Table 11.3.3.1*** contains the capacity factors for egress elements. The capacity of means of escape is sufficient for the occupant load.

For an area has more than one means of egress, the reminding egress capacity has at least 50 percent of the required egress capacity if one of the egress routes is blocked as per ***Paragraph 11.3.1.1.2***. All the staircases in the building serve more than one story and each staircase capacity is based on the portion of the story's occupant load assigned to that stair as per ***Paragraph 11.3.1.4***.

Two restaurants (Assembly occupancies) are located at floor 2 (the level of exit discharge) and floor 3. Their main entrances have provided one-half of the total occupant load of the area as per ***Paragraph 16.2.3.3.2*** and ***16.2.3.3.4***. The main entrances of the restaurants are connected either to the main entrance at the level of exit discharge or to a stairway leading to a public way as per ***Paragraph 16.2.3.3.3***. The minimum width of access exit corridor is 1.12 m as per ***Paragraph 16.2.3.5***.

The minimum stair width is 1.12 m and the minimum door width is 0.81 m. If one exit is block, the other exits are still provided more than 50 percent of the total egress capacity in such area. The capacity of the means of escape is summarised in Table A3-7 to Table A3-19.

Table A3-7: Capacity of Means of Escape

Floor	Activity	Occupant Load for Egress	Egress Width per Occupant		Required Exit Width (m)		Actual Exit Width (m)	
			Stair	Level	Stair	Level	Stair	Level
4	Whole floor	467	0.0076	0.005	3.55	2.33	4.48	3.24
3	Whole floor	4569	0.0076	0.005	34.72	22.85	36.56	24.48
2	Whole floor	5499	0.0076	0.005	41.79	27.50	36.56	24.27
1	Whole floor	403	0.0076	0.005	3.06	2.02	-	94.10
4	Parking Structure	467	0.0076	0.005	3.55	2.33	4.48	3.24
3	Anchor Building – 3	465	0.0076	0.005	3.53	2.33	3.53	2.43
	Anchor Building – 4	465	0.0076	0.005	3.53	2.33	3.53	2.43
	Shopping Mall	3585	0.0076	0.005	27.25	17.93	27.25	18.00
	Car Park	54	0.0076	0.005	0.41	0.27	2.24	1.62
2	Anchor Building - 1	930	0.0076	0.005	7.07	4.65	7.07	4.65
	Anchor Building - 2	930	0.0076	0.005	7.07	4.65	7.07	4.65
	Shopping Mall	3585	0.0076	0.005	27.25	17.93	27.25	18.00
	Car park	54	0.0076	0.005	0.41	0.27	2.24	1.62
1	Storage - 1	14	0.0076	0.005	0.11	0.07	-	1.62
	Storage - 2	11	0.0076	0.005	0.08	0.06	-	1.62
	Storage - 3	14	0.0076	0.005	0.11	0.07	-	1.62
	Storage - 4	8	0.0076	0.005	0.06	0.04	-	1.62
	Parking Structure	360	0.0076	0.005	2.74	1.80	-	58.0

NOTES:

1. The aggregate width of aisles shall not be less than 0.915 m as per ***Section 27.2.5.4***
2. The width of aisles is more than 1.525 m and each aisle has direct path to an exit for Class A mercantile occupancies in accordance with Paragraph 27.2.5.4
3. Checkout stands shall provide at least one-half of the required exits ($\geq$ 0.5 m)
4. Carts and Buggies shall meet the requirements specified in ***Paragraph 27.2.5.7***

Table A3-8: Egress capacity on floor 4

Floor 4: Parking Structure		
Exit	**Stairways Width (m)**	**Level Components Width (m)**
1	1.12	0.81
2	1.12	0.81
3	1.12	0.81
4	1.12	0.81
Total	**4.48**	**3.24**

Table A3-9: Egress capacity for anchor buildings on floor 3

Floor 3: Anchor Buildings		
Exit	**Stairways Width (m)**	**Level Components Width (m)**
1	1.18	0.81
2	1.18	0.81
3	1.18	0.81
Total	**3.53**	**2.43**

Table A3-10: Egress capacity for retail spaces on floor 3

Floor 3: Retail spaces		
Exit	**Stairways Width (m)**	**Level Components Width (m)**
1	3.50	3.50
2	3.50	3.50
3	4.05	2.20
4	4.05	2.20
5	4.05	2.20
6	4.05	2.20
7	4.05	2.20
Total	**27.25**	**18.00**

Table A3-11: Egress capacity for parking structure on floor 3

Floor 3: Parking Structure		
Exit	**Stairways Width (m)**	**Level Components Width (m)**
1	1.12	0.81
2	1.12	0.81
Total	**2.24**	**1.62**

Table A3-12: Egress capacity for anchor buildings on floor 2

Floor 2: Anchor Buildings		
Exit	**Stairways Width (m)**	**Level Components Width (m)**
1	2.36	1.55
2	2.36	1.55
3	2.36	1.55
Total	**7.07**	**4.65**

Table A3-13: Egress capacity for retail spaces on floor 2

Floor 2: Retail Spaces		
Exit	**Stairways Width (m)**	**Level Components Width (m)**
1	7.00	7.00
2	4.05	2.20
3	4.05	2.20
4	4.05	2.20
5	4.05	2.20
6	4.05	2.20
Total	**27.25**	**18.00**

Table A3-14: Egress capacity for parking structure on floor 2

Floor 2: Parking Structure		
Exit	**Stairways Width (m)**	**Level Components Width (m)**
1	1.12	0.81
2	1.12	0.81
Total	**2.24**	**1.62**

Table A3-15: Egress capacity for storage-1 on floor 1

Floor 1: Storage – 1		
Exit	**Stairways Width (m)**	**Level Components Width (m)**
1	-	0.81
2	-	0.81
Total	-	**1.62**

Table A3-16: Egress capacity for storage-2 on floor 1

Floor 1: Storage – 2		
Exit	**Stairways Width (m)**	**Level Components Width (m)**
1	-	0.81
2	-	0.81
Total	-	**1.62**

Table A3-17: Egress capacity for storage-3 on floor 1

Floor 1: Storage – 3		
Exit	**Stairways Width (m)**	**Level Components Width (m)**
1	-	0.81
2	-	0.81
Total	-	**1.62**

Table A3-18: Egress capacity for storage-4 on floor 1

Floor 1: Storage – 4		
Exit	**Stairways Width (m)**	**Level Components Width (m)**
1	-	0.81
2	-	0.81
Total	-	**1.62**

Table A3-19: Egress capacity for parking structure on floor 1

Floor 1: Parking Structure		
Exit	**Stairways Width (m)**	**Level Components Width (m)**
1	-	6.0
2	-	15.0
3	-	10.0
4	-	25.0
Total	-	**56.0**

A3.6.12 Accessible Means of Egress

As per ***Paragraph 11.5.4.1***, the building requires not less than two accessible means of egress. Class C Mercantile Occupancies are permitted to have a single accessible means of egress because it is permitted to have a single exit as per ***Paragraph 11.5.4.1.2*** and ***Paragraph 27.2.4(4)***. According to the provision of ***Paragraph 27.2.2.12.2***, the building is exempt from having to provide the two accessible rooms or spaces separated from each other by smoke resisting partitions. The building is protected with automatic sprinkler system and each space (except Class C Mercantile Occupancies) provides at least two means of egress routes to create the equivalent of two accessible means of egress.

Parking structure and each storage area on floor 1 is provided two accessible means of egress directly to the outside of building.

Restaurants and open parking structure are located on upper floors and the requirement for accessible means of egress is met by providing areas of refuge with access to two exits. Each area is sprinkler protected and installed with communication system required by ***Paragraph 11.2.12.1.1*** to meet the provisions of area of refuge. Each area is accessible to two exits and serves to provide the equivalent of two accessible means of egress.

A3.6.13 Door Swing and Self-closing Devices

Stair enclosure and horizontal exit are normally not secured in the open position and equipped with self-closing or automatic closing device as per ***Paragraph 11.2.1.8***. The criteria for automatic closing are listed in ***Paragraph 11.2.1.8.2***.

Fire doors shall comply with the requirements of ***Section 8.7*** and shall be self-closing or automatic-closing as per ***Section 8.7.3***.

Doors in the required means of egress are required to be open in the direction of egress travel if there are more than 50 occupants using the door or if the door is used in an exit enclosure.

A3.7 Interior Finish

Interior wall and ceiling finish material can be Class A or Class B or Class C because the building is sprinkler protected. Interior floor finish in all areas can be Class I or Class II or no critical radiant flux rating requirement (no classification required) because the building is sprinkler protected as per ***Section 16.3.3***, ***27.3.3***, ***30.8.3.3*** and ***10.7***. Detailed interior finish requirements are listed in Section 7.1 and 7.2.

A3.7.1 Interior Wall and Ceiling Finish

For the thickness of materials applied directly to the surface of walls and ceilings is less than 0.90 mm, the materials shall not be considered interior finish and shall be exempt from tests simulating actual installation if they are classified as Class A interior wall or ceiling finish.

Interior wall or ceiling finish shall be classified to be Class A, Class B or Class C based on test results from ASTM E 84, Standard Test Method of Surface Burning Characteristics of Building Materials, or UL 723, Standard for Test of Surface Burning Characteristics of Building Materials, or except as follows:

- Exposed portions of structural members is Type IV (2HH) construction
- Interior wall and ceiling finish tested in accordance with NFPA 286, Standard Methods of Fire Tests for Evaluating Contribution of Wall and Ceiling Interior Finish to Room Fire Growth, and are complied with the criteria of ***Paragraph 10.3.6.2***, are classified as Class A in accordance with ASTM E 84 or UL 723

Interior wall and ceiling finishes for the building must be grouped in classes as shown in Table A1-7. Specific materials, trim and incidental finish shall satisfy the requirements in ***Section 10.4*** and ***Section 10.5***.

Table A3-20: Interior Wall and Ceiling Finishes Classification

Classification	Flame Spread Index (FSI)	Smoke Developed Index (SDI)
Class A	0 – 25	0 – 450
Class B	26 – 75	0 – 450
Class C	76 - 200	0 – 450

NOTES:

1. If the use of Class C interior wall and ceiling finish is required, Class A or Class B shall be permitted. If class B interior wall and ceiling finish is required, Class A shall be permitted, as per ***Paragraph 10.3.5***.
2. Interior wall and ceiling finish tested in accordance with NFPA 265, Standard Methods of Fire Tests for Evaluating Room Fire Growth Contribution of Textile Coverings on Full Height Panels and Walls, shall comply with the criteria of ***Paragraph 10.3.6.1***.
3. If an approved automatic sprinkler system is installed, Class C interior wall and ceiling finish materials shall be permitted in any location where Class B is required, and Class B interior wall and ceiling finish materials shall be permitted in any location where Class A is required, as per ***Paragraph 10.7.1***.
4. The flame spread of interior finish on walls and ceilings in exit enclosure shall be limited to Class A or Class B as per ***Paragraph 11.1.4.1***

A3.7.2 Interior Floor Finish

Interior floor finish such as carpet and carpetlike interior floor finishes shall comply with ASTM D 2859, Standard Test Method for Ignition Characteristics of Finished Textile Floor Covering Materials.

Interior floor finishes shall be classified to be Class I or Class II based on test results from NFPA 253, Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source, or ASTM E 648, Standard Test Method for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source.

Interior floor finishes for the building must be grouped in classes as shown in Table A1-8.

Table A3-21: Interior floor Finishes Classification

Classification	Critical Radiant Flux
Class I	$\geq 0.45\ W/cm^2$
Class II	$\geq 0.22\ W/cm^2$ and $< 0.45\ W/cm^2$

NOTES:

1 Floor coverings, other than carpet, that are judged to represent an unusual hazard shall have a minimum critical radiant flux of 0.1 W/cm^2, as per ***Paragraph 10.6.2***.

2 If an approved automatic sprinkler system is installed, Class II interior floor finish materials shall be permitted in any location where Class I is required; and where Class II is required, no critical radiant flux rating shall be required, as per ***Paragraph 10.7.2***.

3 The flame spread of interior finish on floor in exit enclosure, including stair treads and risers, shall be less than Class II as per ***Paragraph 11.1.4.2***.

A3.8 Fire Fighting

A fire department access to the building is to meet the requirements of ***Section 7.1.5.2***. The vehicular access shall not be more than 15 m away from an exterior door that provides access to the building and that can be opened from outside as per ***Paragraph 7.1.5.2.2.1*** and an unavailable access road around the exterior of the building shall not be over 137 m as per ***Paragraph 7.1.5.2.3.2***. ***Paragraph 7.1.5.2.5.1*** and ***Paragraph 7.1.5.2.5.4*** state the vehicular access shall have at least 6.1 m unobstructed width, at least 4.1 m unobstructed height and a dead end vehicular access in excess of 46 m in length is not allowed.

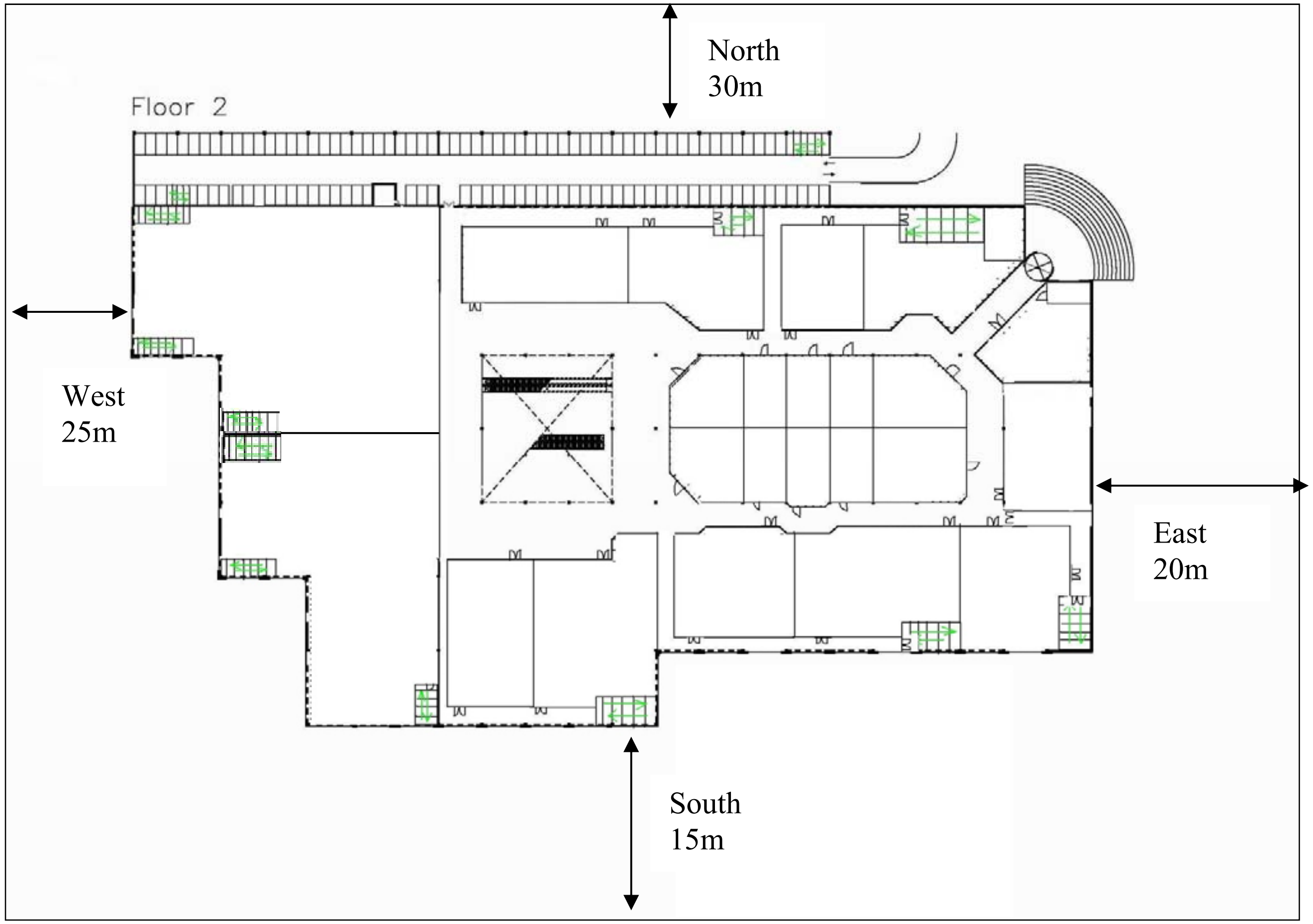


Figure A3-1: Building Layout and Relevant Boundary

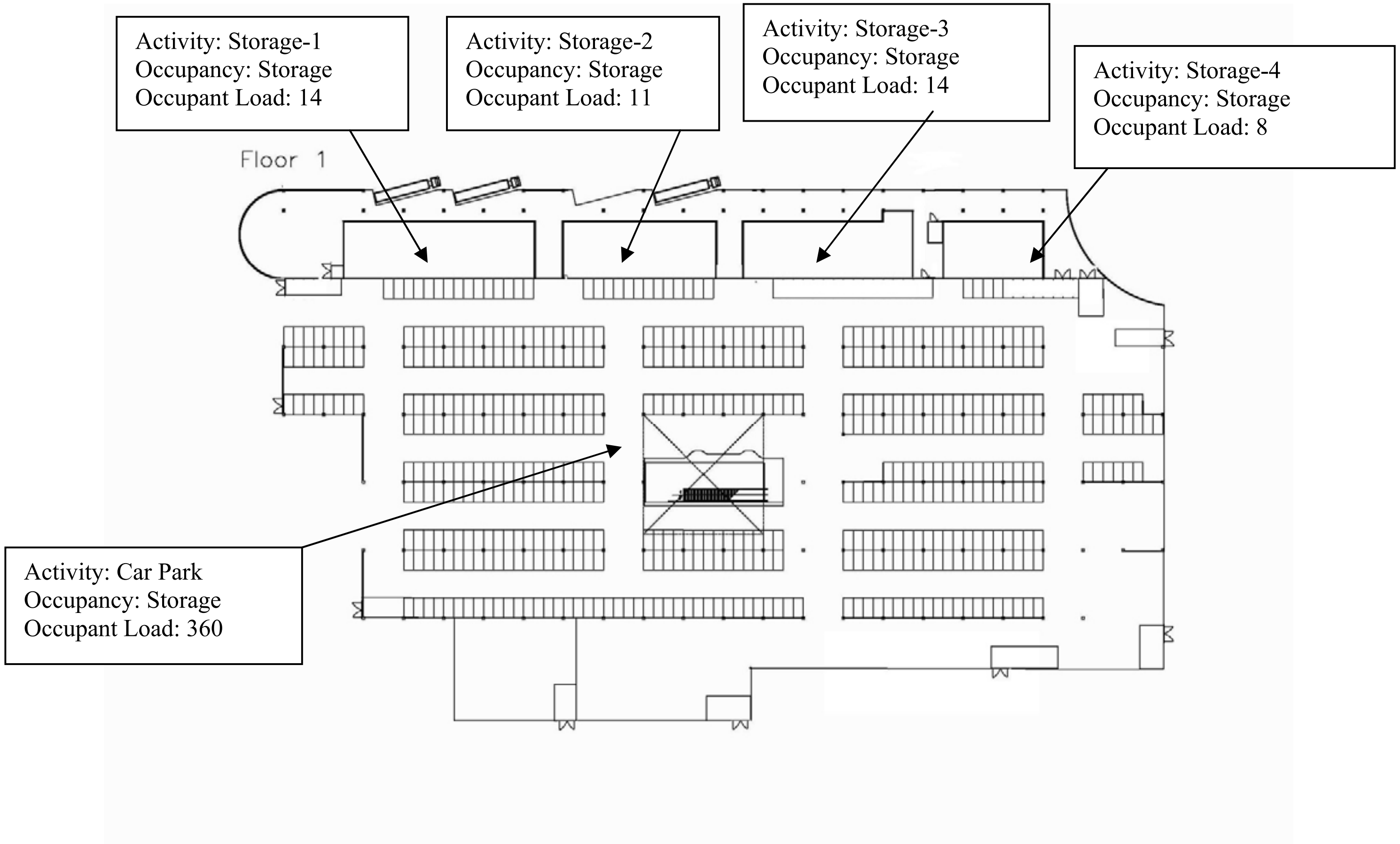


Figure A3-2: Activity, occupancy type and occupant load on floor 1

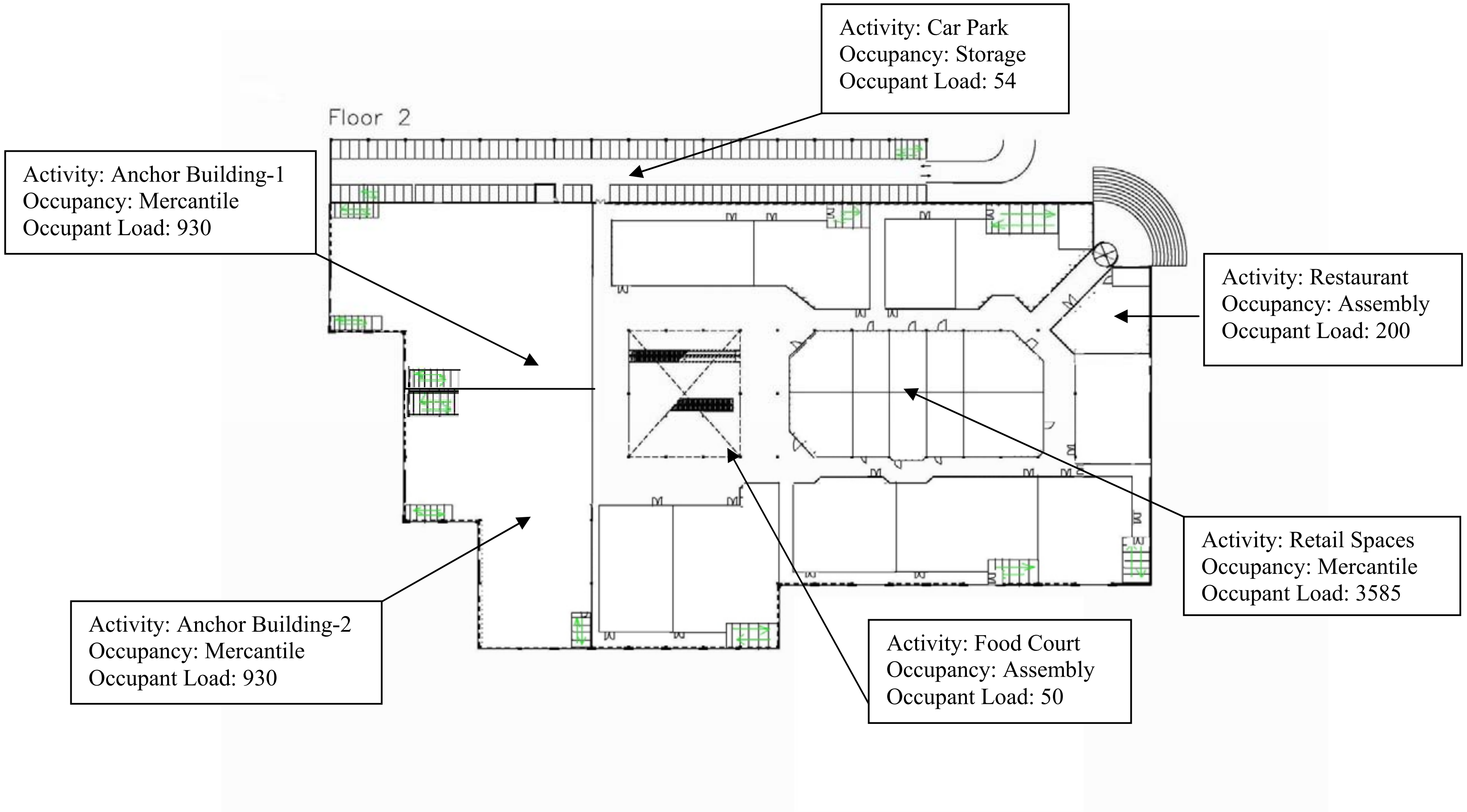


Figure A3-3: Activity, occupancy type and occupant load on floor 2

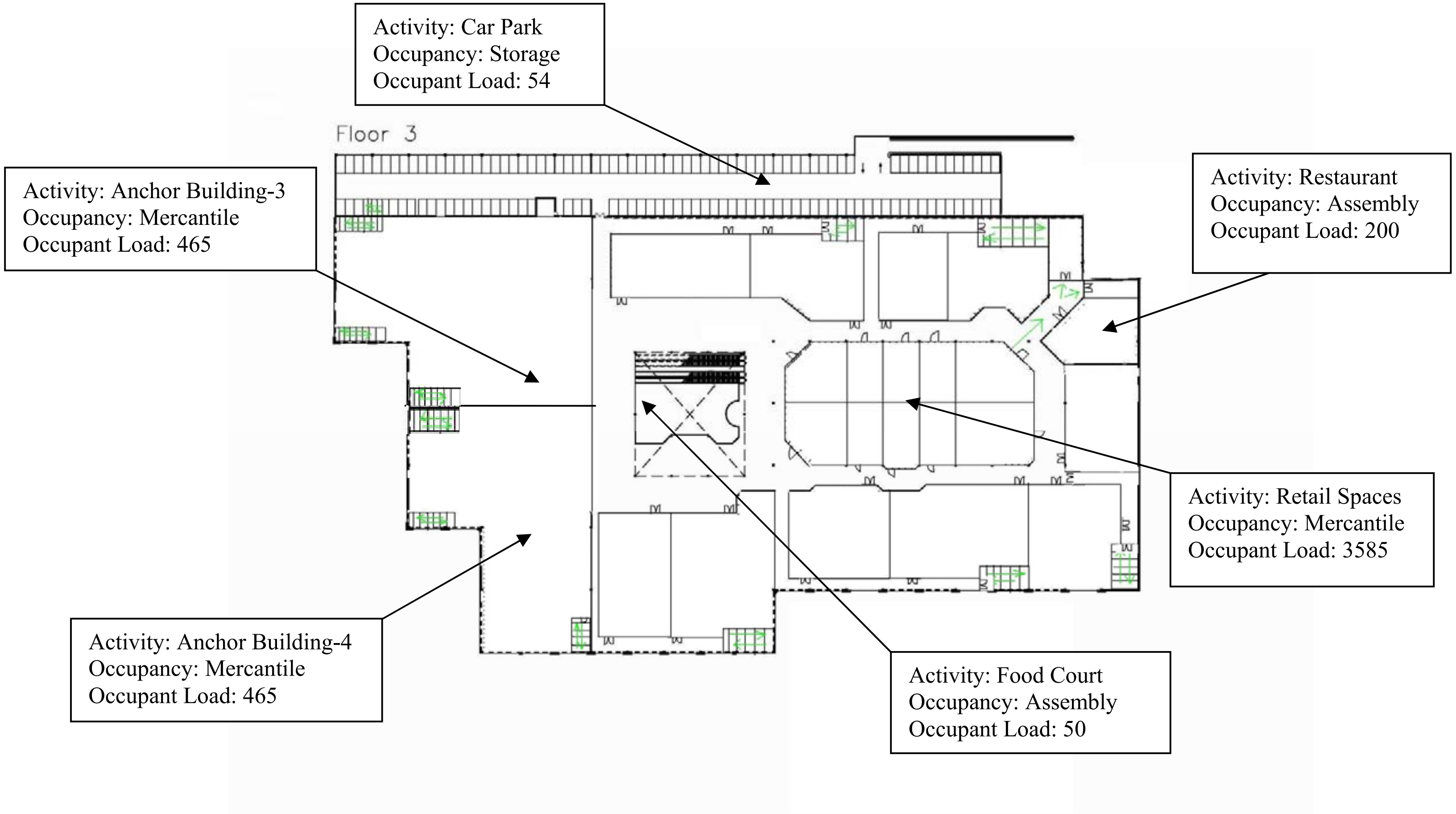


Figure A3-4: Activity, occupancy type and occupant load on floor 3

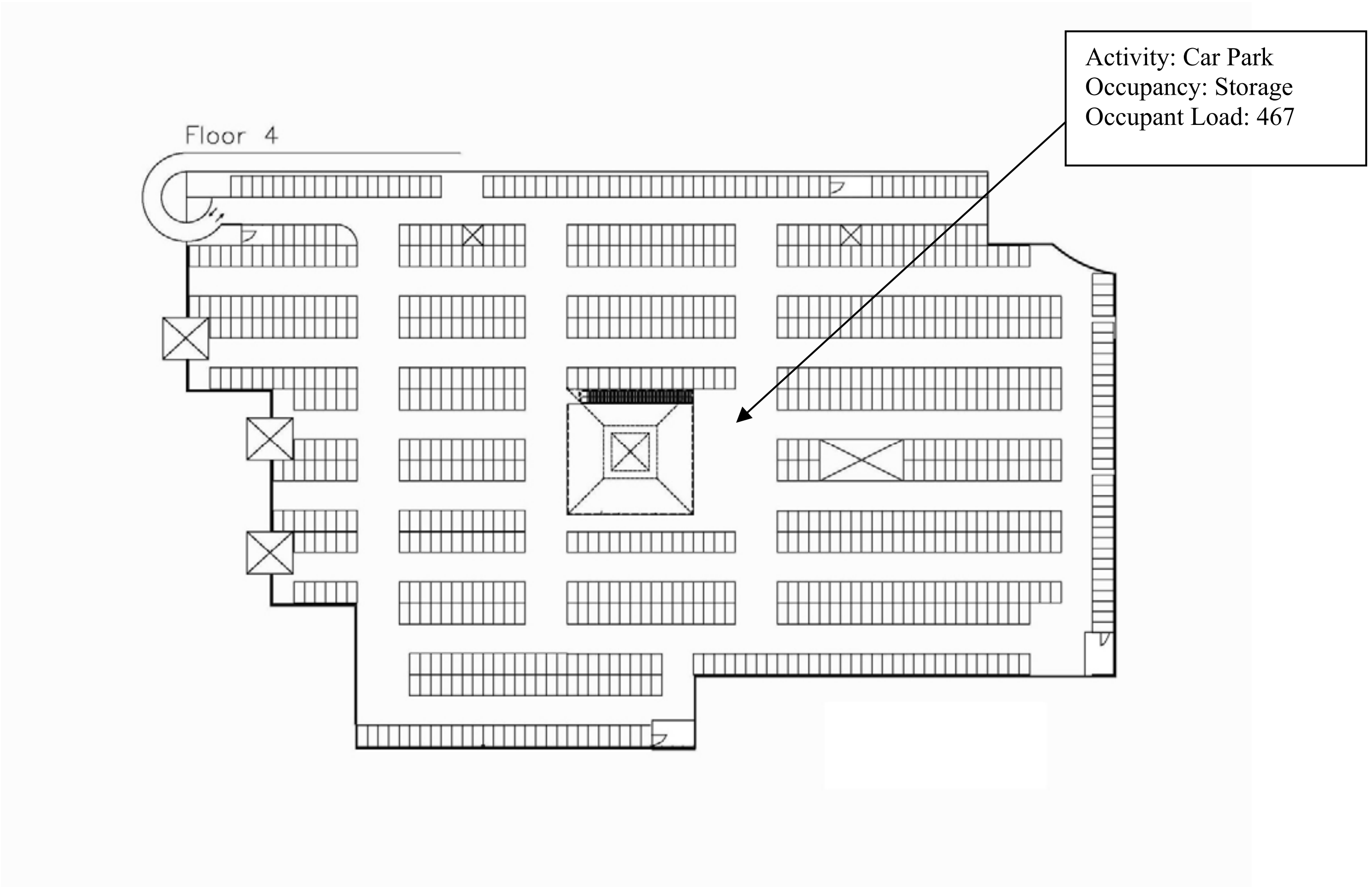


Figure A3-5: Activity, occupancy type and occupant load on floor 4

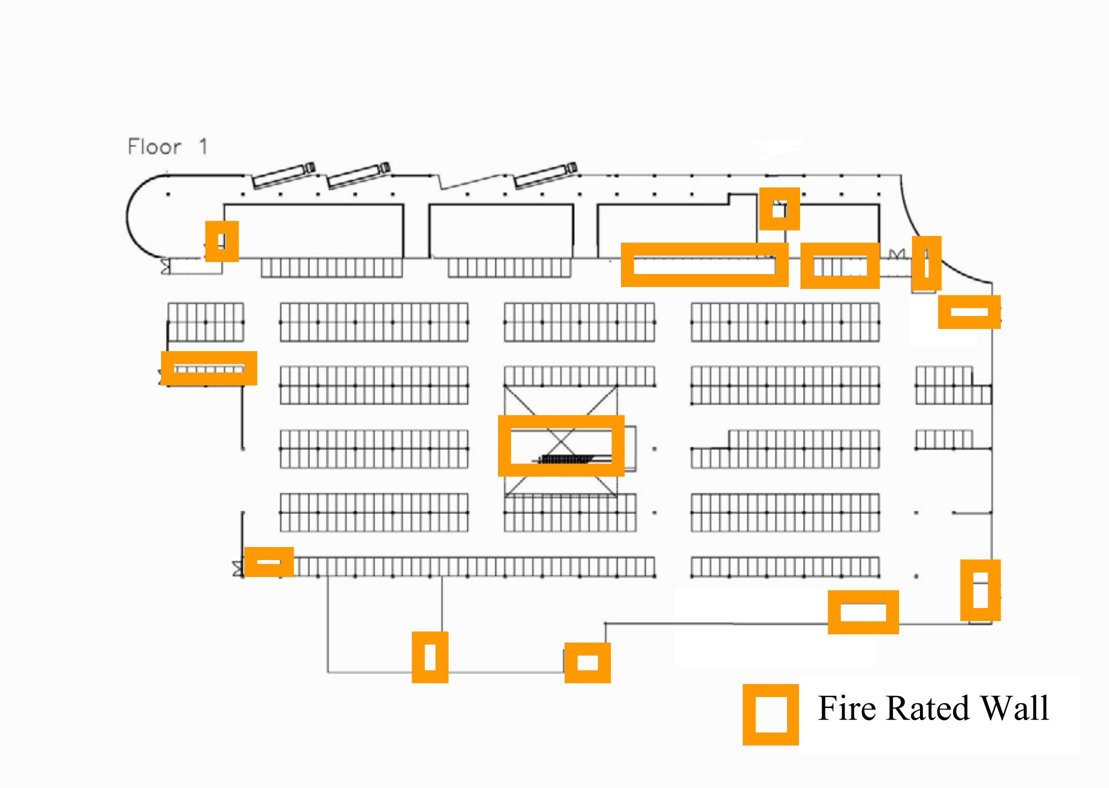


Figure A3-6: Required fire protection system in floor 1

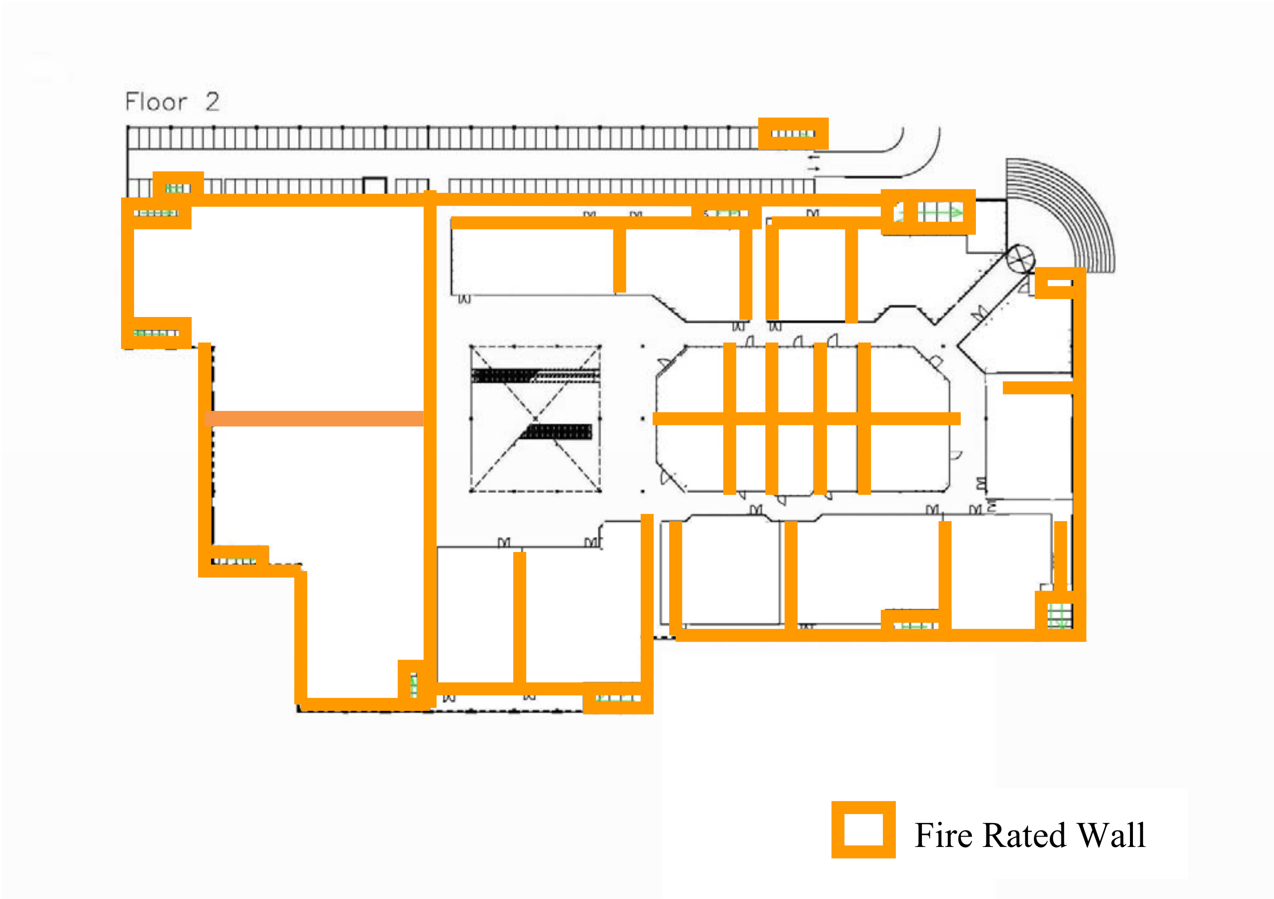


Figure A3-7: Required fire protection system in floor 2

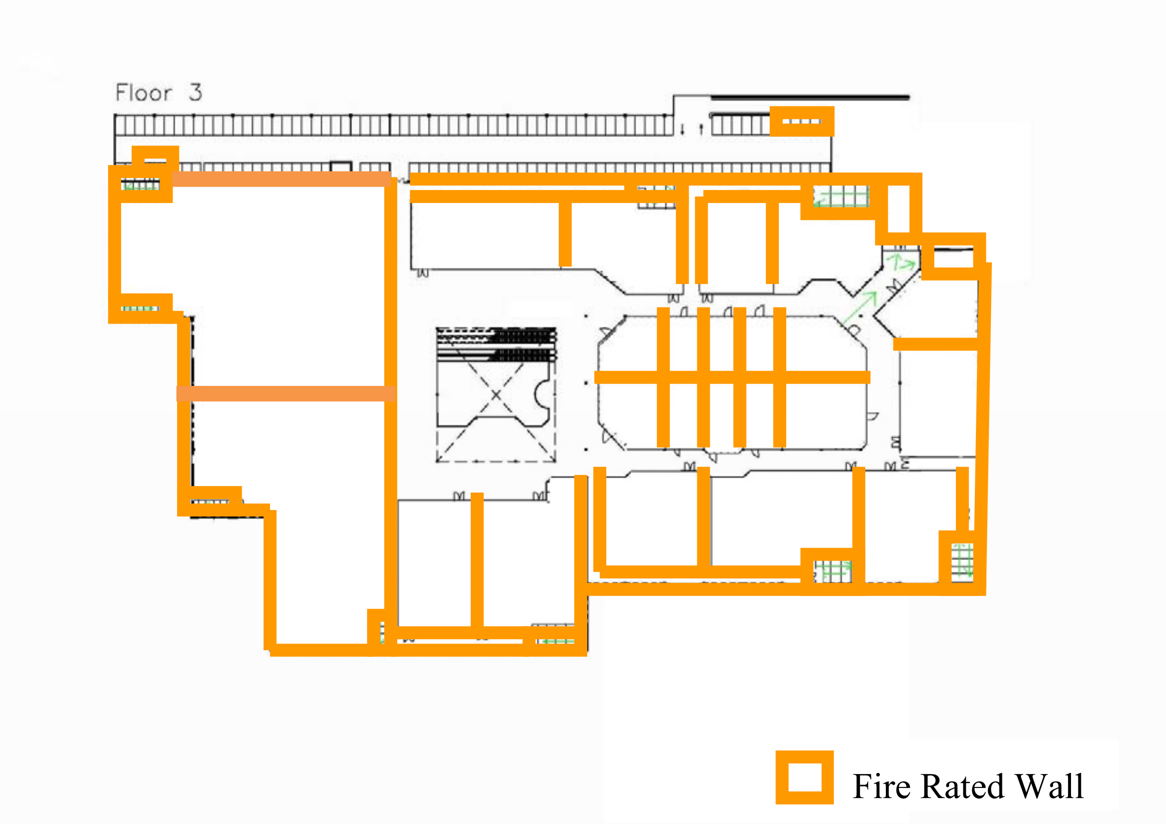


Figure A3-8: Required fire protection system in floor 3

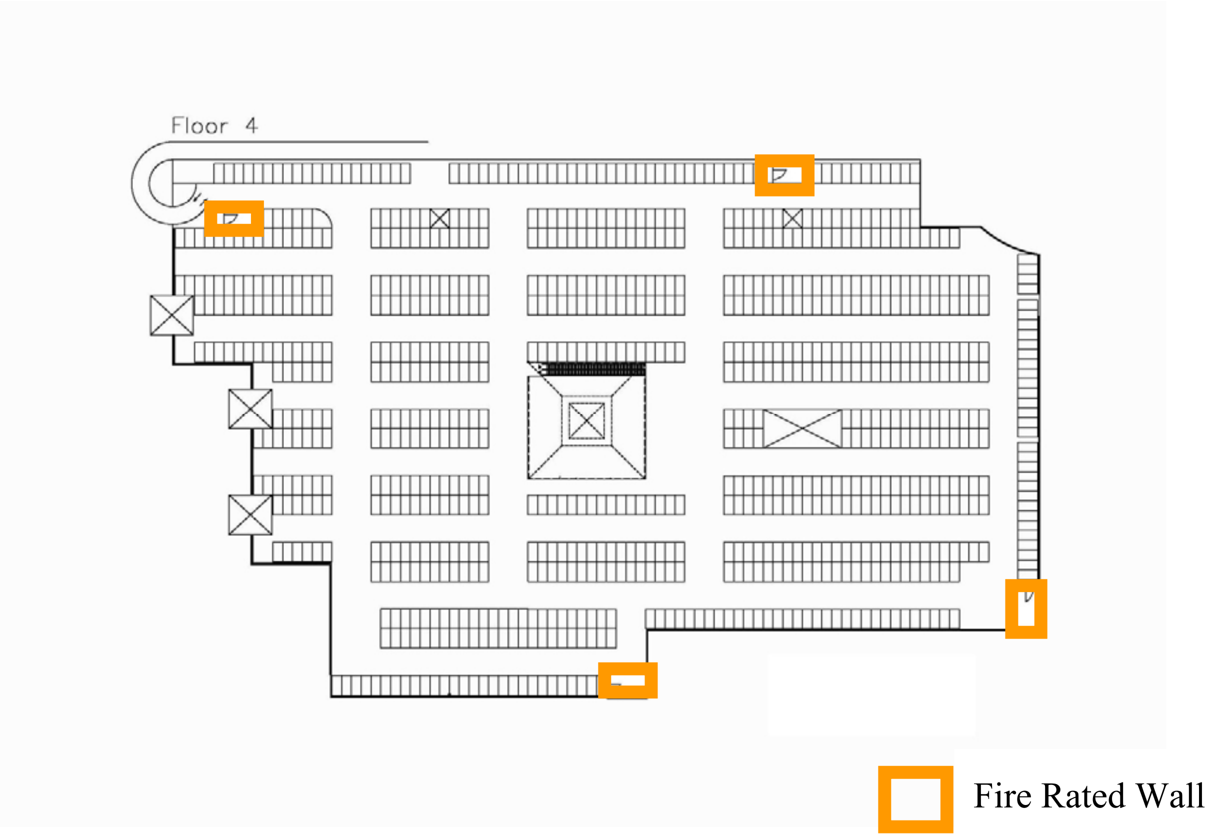


Figure A3-9: Required fire protection system in floor 4

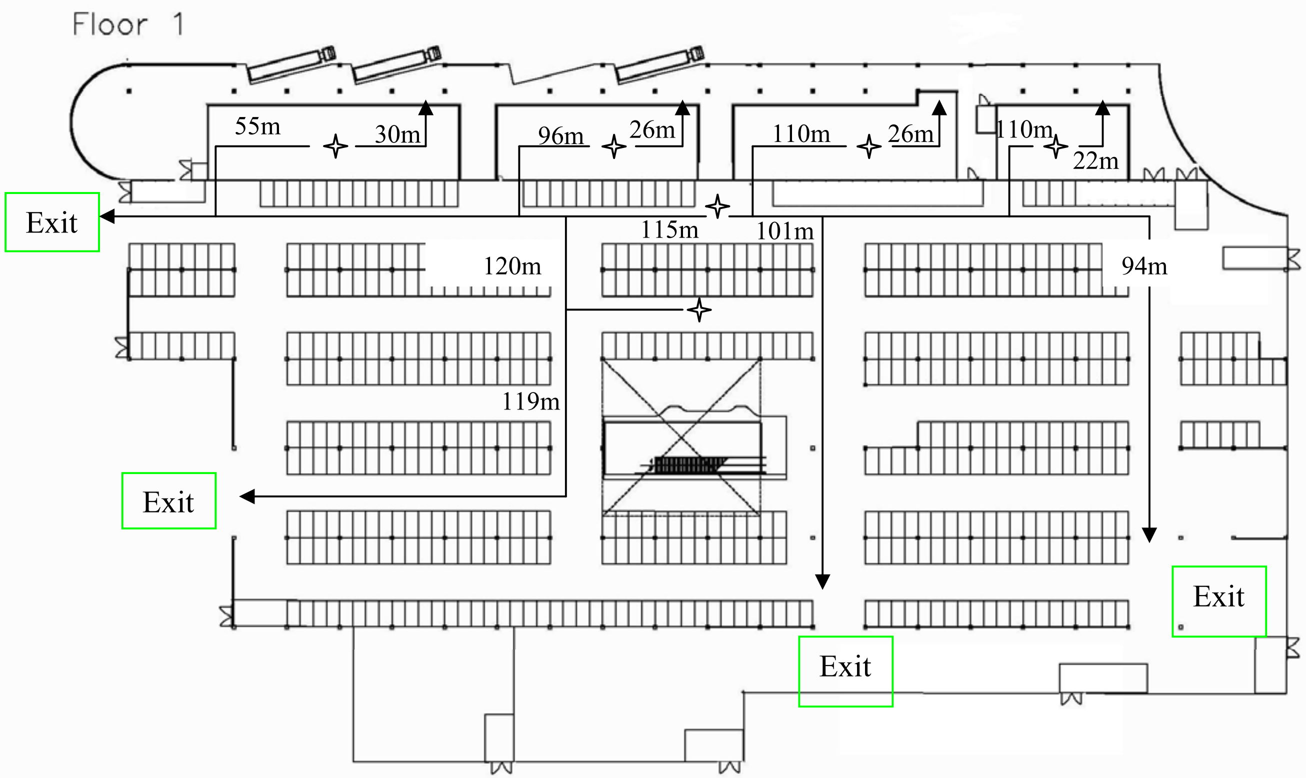


Figure A3-10: Exits and egress routes on floor 1

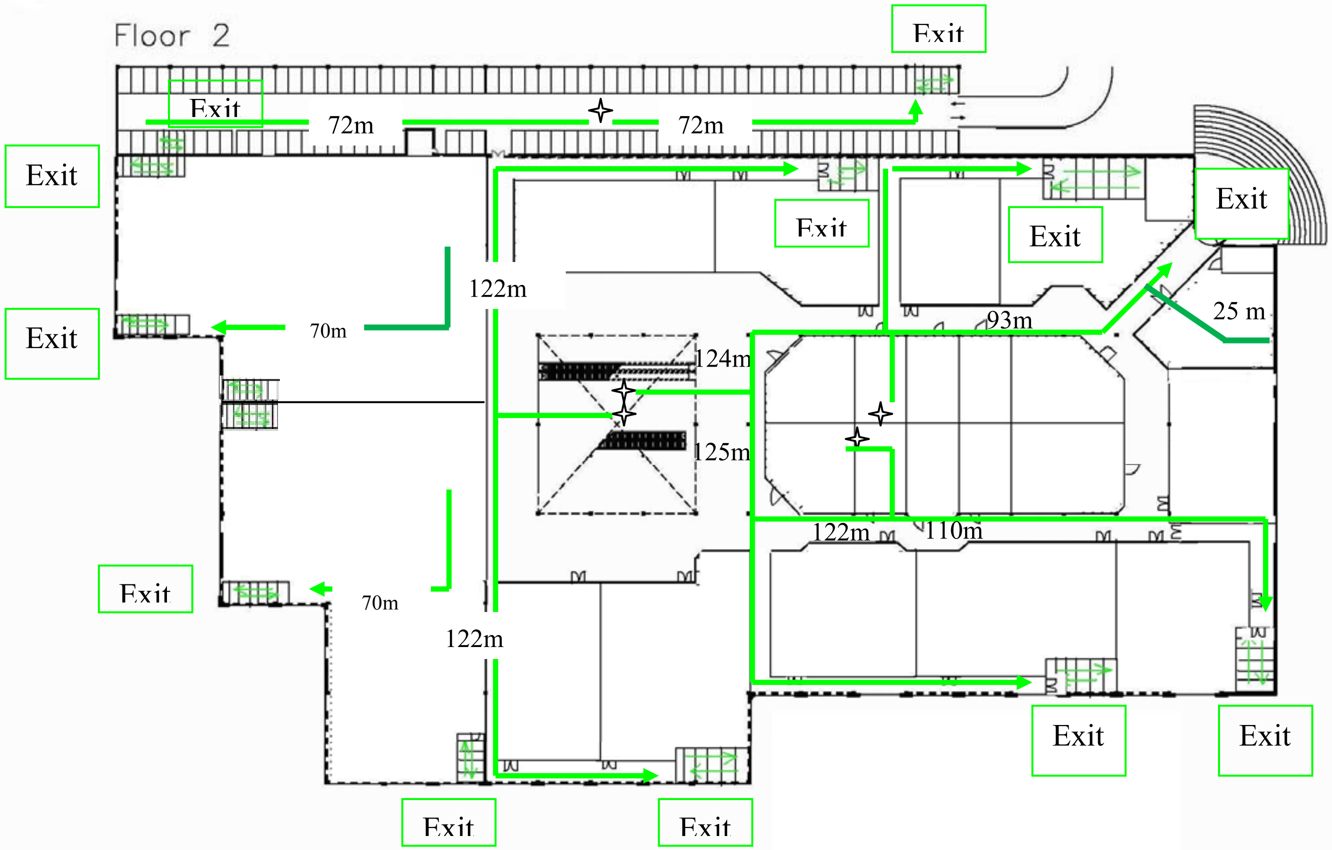


Figure A3-11: Exits and egress routes on floor 2

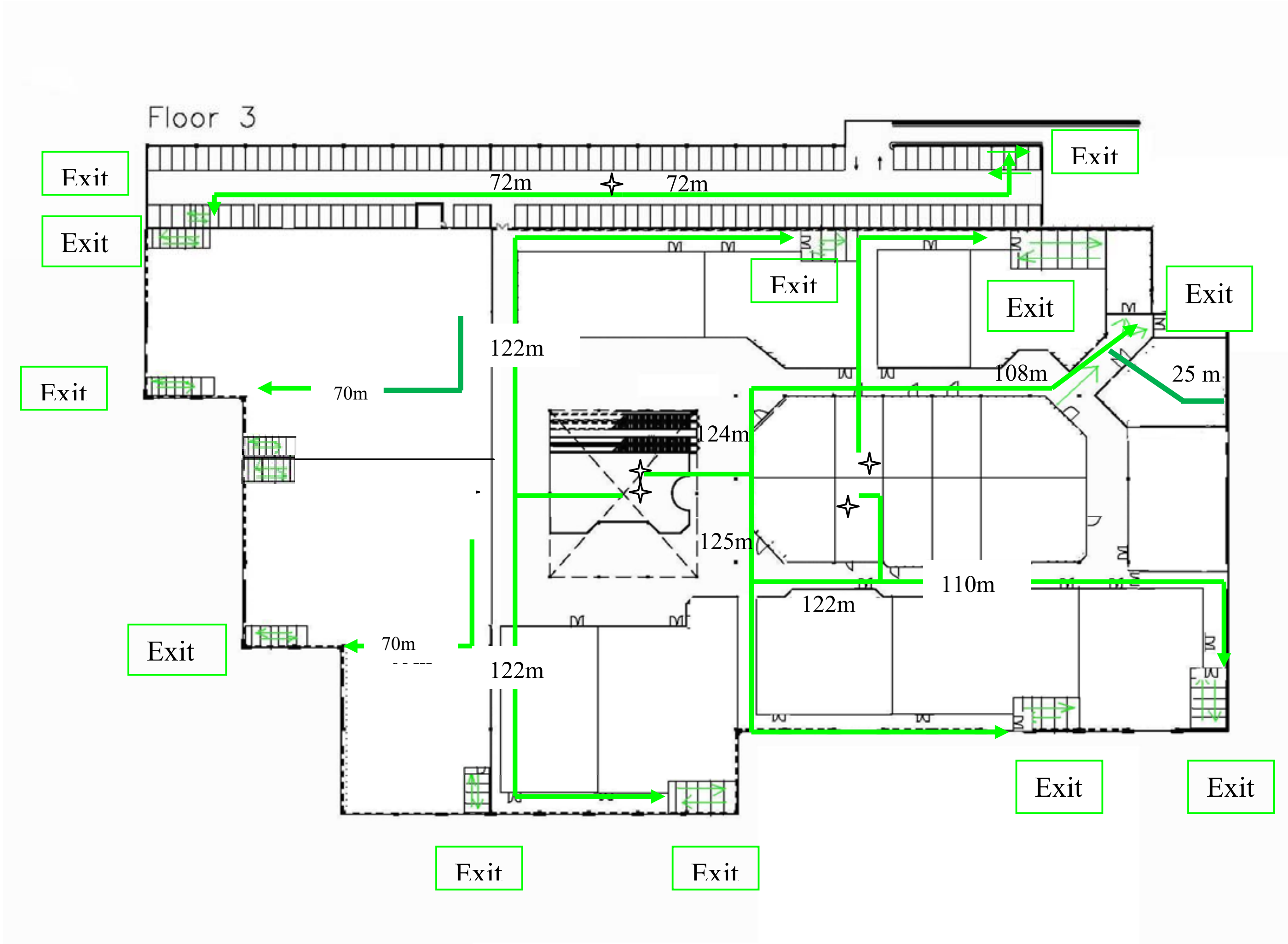


Figure A3-12: Exits and egress routes on floor 3

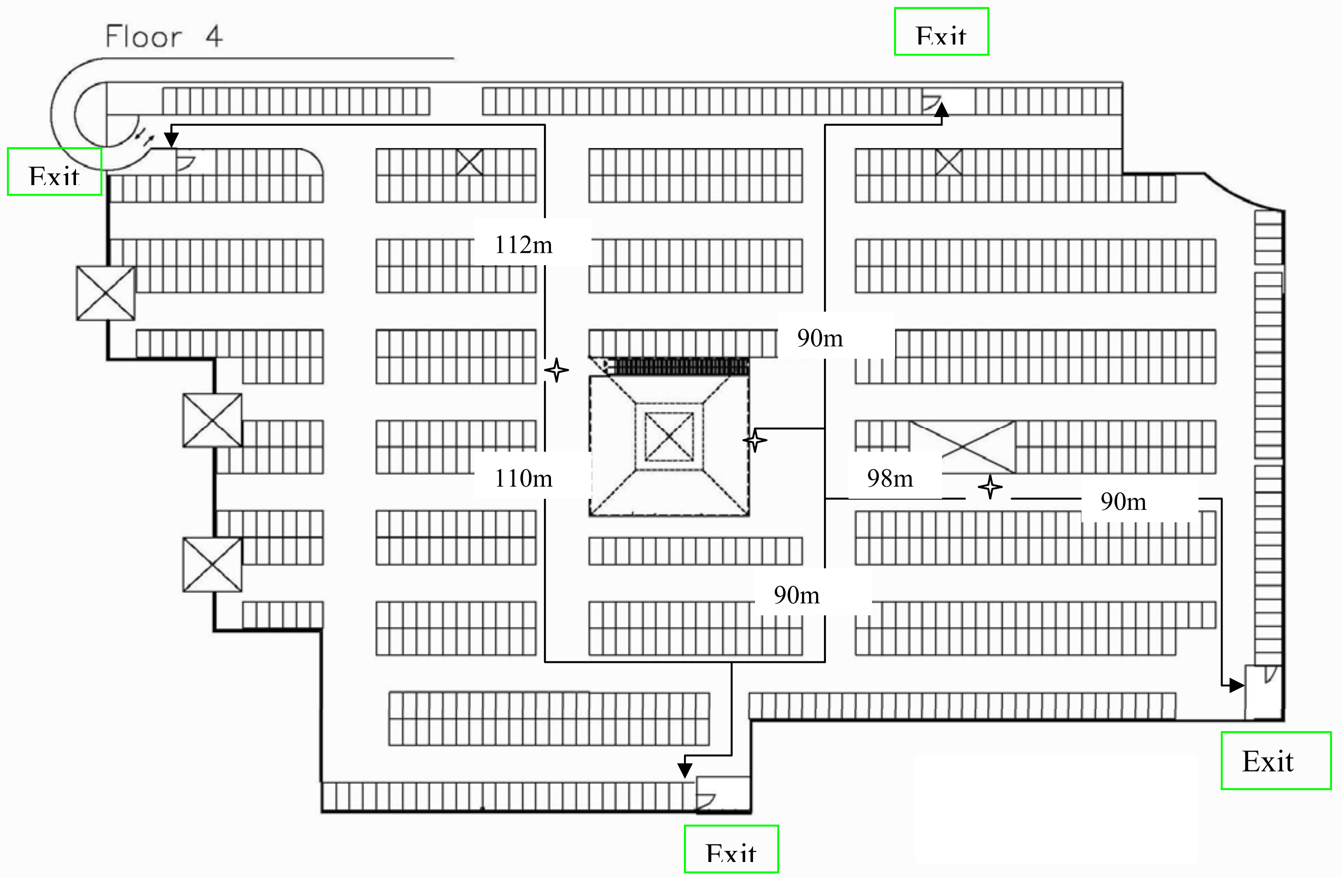


Figure A3-13: Exits and egress routes on floor 4

Appendix B: Evacuation Calculation

Appendix B1: Retail Area Fire

The building has the following features related to the egress calculations:

1. The building is a single storey
2. Floor to mezzanine floor is 3.5 m
3. Two stairways are located at the ends of the mezzanine
4. Each stair is 1.2 m wide (clear width)
5. Stair riser are 0.175 m wide and treads are 0.33 m high
6. There is a 0.81 m clear width door at each stairway
7. All final exits are 0.81 m clear width door except there are three 1.0 m clear width doors in the retail area

B1.1 Detection Time

Detection time, 77s, from the sprinkler system was simulated in BRANZFIRE zone modeling for retail area fire.

B1.2 Pre-movement time

B1.2.1Retail Area

The pre-movement time, 60s, was taken in the retail area as the occupants are awake, unfamiliar with the building and are in the fire of origin.

B1.2.2Storage Area

The pre-movement time, 60s, was taken in the storage area as the occupants are awake, familiar with the building and are remote from the fire of origin.

B1.2.3Drive Thru Area

The pre-movement time, 120s, was taken in the drive thru area as the occupants are awake, unfamiliar with the building and are remote from the fire of origin.

B1.2.4Mezzanine

The pre-movement time, 60s, was taken in the mezzanine as the occupants are awake, familiar with the building and are remote from the fire of origin.

B1.3 Travel Time

B1.3.1 Retail Area

NFPA5000 gives an occupant density of 2.8 m^2 per person (0.4 people per square meter). Using the occupant density, the occupant load is 600 people in the retail area. The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied.

The travel distance is measured from the furthest point in the area to the nearest exit, giving the travel distance of 33 m and the horizontal travel time of 28 s.

B1.3.2 Storage Area

NFPA5000 gives an occupant density of 27.9 m^2 per person (0.04 people per square meter). Using the occupant density, the occupant load is 12 people in the storage area. The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied.

The travel distance is measured from the furthest point in the area to the outside of building, giving the travel distance of 27 m and the horizontal travel time of 23 s.

The travel distance is measured from the furthest point in the area to the outside of building through the stairway, giving the travel distance of 28 m and the horizontal travel time of 24 s.

B1.3.3 Drive Thru Area

NFPA5000 gives an occupant density of 27.9 m^2 per person (0.04 people per square meter). Using the occupant density, the occupant load is 15 people in the drive thru area. The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied.

The travel distance is measured from the furthest point in the area to the nearest exit, giving the travel distance of 24 m and the horizontal travel time of 20 s.

B1.3.4Mezzanine

NFPA5000 gives an occupant density of 9.3 m^2 per person (0.11 people per square meter). Using the occupant density, the occupant load is 29 people in the mezzanine. The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) and the maximum vertical travel speed (1.00 m/s) are applied.

The travel distance is measured from the furthest point in the mezzanine to the open stairway, giving the horizontal travel distance of 23 m and the travel time of 20 s.

The travel distance is measured from the furthest point in the mezzanine to the enclosed stairway, giving the horizontal travel distance of 34 m and the travel time of 29 s.

The travel distance is measured from the furthest point in the mezzanine to the outside of the building through the retail area, giving the horizontal travel distance of 66 m, the vertical travel distance of 7.5 m, the horizontal travel time of 56 s, the vertical travel time of 8 s, and total traveling time of 64 s.

B1.4 Flow Time and Queuing Time

B1.4.1 Retail Area

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. There are three 1.0 m clear wide doors in the retail area leading to the outside of building. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 2.1 m. Using Equation 7, the actual flow is 2.5 people/s. Assuming half of the occupant from the mezzanine are traveling through the retail area which gives the total occupant of 615 people queuing at the doorway. The queuing time is 246 s from Equation 8.

B1.4.2 Storage Area

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied.

There is a 0.81 m clear wide door in the storage area leading to the outside. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 0.51 m. Using Equation 7, the actual flow is 0.66 people/s. Assuming half of the occupant (6 people) in the storage area are queuing at the doorway. The queuing time is 9 s from Equation 8.

Apart from the direct exit to the outside, occupants can travel to the outside through the enclosed stairway. There is a 0.81 m clear wide door in the stairway leading to the outside. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 0.51 m. Using Equation 7, the actual flow is 0.66 people/s. Assuming half of the occupant (6 people) in the storage area and half of the occupant (15 people) in the mezzanine are queuing at the doorway. The queuing time is 22 s from Equation 8.

B1.4.3 Drive Thru Area

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. There are two 0.81 m clear wide doors in the retail area leading to the outside of building. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 1.02 m. Using Equation 7, the actual flow is 1.33 people/s. The total occupant of 15 people queuing at the doorway. The queuing time is 11 s from Equation 8.

B1.4.4 Mezzanine

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied.

There is a 0.81 m clear wide door in the mezzanine leading to each stairway. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 0.51 m. Using Equation 7, the actual flow is 0.66 people/s for each stairway. Assuming half of the occupants (15 people) in the mezzanine is queuing at each stairway. The queuing time is 22 s from Equation 8.

Once the occupants clear the mezzanine, they are either queuing at the enclosed stairway with the storage occupants or queuing at the retail area with the retail occupants. The queuing time in the enclosed stairway is 32 s and the queuing time in the retail area is 246 s.

B1.5 RSET Results

B1.5.1Retail Area

The last occupant in the retail area will take 28 s to travel to an exit and the population of 615 people will require 246 s to pass through the exit. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants in retail area is, RSET = 77 + 60 + 246 = 383 s.

B1.5.2 Storage Area

The last occupant in the storage area will take 23 s to directly travel to an exit and the population of 12 people will require 9 s to pass through the exit. The travelling time governs and the queuing time is excluded from the RSET. The RSET for the occupants to clear storage area directly to the outside is, RSET = 77 + 60 + 23 = 160 s.

The last occupant in the storage area will take 24 s to travel to an exit through the stairway and the population of 12 people will require 22 s to pass through the exit. The travelling time governs and the queuing time is excluded from the RSET. The RSET for the occupants to clear storage area through stairway is, RSET = 77 + 60 + 24 = 161 s.

B1.5.3 Drive Thru Area

The last occupant in the retail area will take 20 s to travel to an exit and the population of 15 people will require 11 s to pass through the exit. The travelling time governs and the queuing time is excluded from the RSET. The RSET for the occupants in the area is, RSET = 77 + 120 + 20 = 217 s.

B1.5.4 Mezzanine

The last occupant in the mezzanine will take 20 s to travel to the open stairway and the population of 29 people will require 22 s to pass through the open stairway. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants to clear mezzanine to the open stair is, RSET = 77 + 60 + 22 = 159 s.

The last occupant in the mezzanine will take 29 s to travel to an exit through the enclosed stairway and the population of 29 people will require 22 s to pass through the exit. The travelling time governs and the queuing time is excluded from the RSET. The RSET for the occupants to clear mezzanine to the outside through stairway is, RSET = 77 + 60 + 29 = 166 s.

The last occupant in the mezzanine will take 64 s to travel to an exit in the retail area through the open stairway and the population of 615 people will require 246 s to pass through the exit. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants to clear mezzanine to the outside through retail area is, RSET = 77 + 60 + 246 = 383s.

Appendix B2: Storage Area Fire

The building has the following features related to the egress calculations:

1. The building is a single storey
2. Floor to mezzanine floor is 3.5 m
3. Two stairways are located at the ends of the mezzanine
4. Each stair is 1.2 m wide (clear width)
5. Stair riser are 0.175 m wide and treads are 0.33 m high
6. There is a 0.81 m clear width door at each stairway
7. All final exits are 0.81 m clear width door except there are three 1.0 m clear width doors in the retail area

B2.1 Detection Time

Detection time, 70s, from the sprinkler system was simulated in BRANZFIRE zone modeling for storage area fire.

B2.2 Pre-movement time

B2.2.1 Retail Area

The pre-movement time, 120s, was taken in the retail area as the occupants are awake, unfamiliar with the building and are remote from in the fire of origin.

B2.2.2 Storage Area

The pre-movement time, 30s, was taken in the storage area as the occupants are awake, familiar with the building and are in the fire of origin.

B2.2.3 Drive Thru Area

The pre-movement time, 120s, was taken in the drive thru area as the occupants are awake, unfamiliar with the building and are remote from the fire of origin.

B2.2.4 Mezzanine

The pre-movement time, 60s, was taken in the mezzanine as the occupants are awake, familiar with the building and are remote from the fire of origin.

B2.3 Travel Time

B2.3.1 Retail Area

NFPA5000 gives an occupant density of 2.8 m^2 per person (0.4 people per square meter). Using the occupant density, the occupant load is 600 people in the retail area. The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied.

The travel distance is measured from the furthest point in the area to the nearest exit, giving the travel distance of 33 m and the horizontal travel time of 28 s.

B2.3.2 Storage Area

NFPA5000 gives an occupant density of 27.9 m^2 per person (0.04 people per square meter). Using the occupant density, the occupant load is 12 people in the storage area. The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied.

The travel distance is measured from the furthest point in the area to the outside of building, giving the travel distance of 27 m and the horizontal travel time of 23 s.

The travel distance is measured from the furthest point in the area to the outside of building through the stairway, giving the travel distance of 28 m and the horizontal travel time of 24 s.

B2.3.3 Drive Thru Area

NFPA5000 gives an occupant density of 27.9 m^2 per person (0.04 people per square meter). Using the occupant density, the occupant load is 15 people in the drive thru area. The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied.

The travel distance is measured from the furthest point in the area to the nearest exit, giving the travel distance of 24 m and the horizontal travel time of 20 s.

B2.3.4 Mezzanine

NFPA5000 gives an occupant density of 9.3 m^2 per person (0.11 people per square meter). Using the occupant density, the occupant load is 29 people in the mezzanine. The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) and the

maximum vertical travel speed (1.00 m/s) are applied.

The travel distance is measured from the furthest point in the mezzanine to the open stairway, giving the horizontal travel distance of 23 m and the travel time of 20 s.

The travel distance is measured from the furthest point in the mezzanine to the enclosed stairway, giving the horizontal travel distance of 34 m and the travel time of 29 s.

The travel distance is measured from the furthest point in the mezzanine to the outside of the building through the retail area, giving the horizontal travel distance of 66 m, the vertical travel distance of 7.5 m, the horizontal travel time of 56 s, the vertical travel time of 8 s, and total traveling time of 64 s.

B2.4 Flow Time and Queuing Time

B2.4.1 Retail Area

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. There are three 1.0 m clear wide doors in the retail area leading to the outside of building. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 2.1 m. Using Equation 7, the actual flow is 2.5 people/s. Assuming half of the occupant from the mezzanine are traveling through the retail area which gives the total occupant of 615 people queuing at the doorway. The queuing time is 246 s from Equation 8.

B2.4.2 Storage Area

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied.

There is a 0.81 m clear wide door in the storage area leading to the outside. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 0.51 m. Using Equation 7, the actual flow is 0.66 people/s. Assuming half of the occupant (6 people) in the storage area are queuing at the doorway. The queuing time is 9 s from Equation 8.

Apart from the direct exit to the outside, occupants can travel to the outside through the enclosed stairway. There is a 0.81 m clear wide door in the stairway leading to the outside.

From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 0.51 m. Using Equation 7, the actual flow is 0.66 people/s. Assuming half of the occupant (6 people) in the storage area and half of the occupant (15 people) in the mezzanine are queuing at the doorway. The queuing time is 22 s from Equation 8.

B2.4.3 Drive Thru Area

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. There are two 0.81 m clear wide doors in the retail area leading to the outside of building. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 1.02 m. Using Equation 7, the actual flow is 1.33 people/s. The total occupant of 15 people queuing at the doorway. The queuing time is 11 s from Equation 8.

B2.4.4 Mezzanine

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied.

There is a 0.81 m clear wide door in the mezzanine leading to each stairway. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 0.51 m. Using Equation 7, the actual flow is 0.66 people/s for each stairway. Assuming half of the occupants (15 people) in the mezzanine is queuing at each stairway. The queuing time is 22 s from Equation 8.

Once the occupants clear the mezzanine, they are either queuing at the enclosed stairway with the storage occupants or queuing at the retail area with the retail occupants. The queuing time in the enclosed stairway is 32 s and the queuing time in the retail area is 246 s.

B2.5 RSET Results

B2.5.1 Retail Area

The last occupant in the retail area will take 28 s to travel to an exit and the population of 615 people will require 246 s to pass through the exit. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants in retail area is, RSET = 70 + 120 + 246 = 436 s.

B2.5.2 Storage Area

The last occupant in the storage area will take 23 s to directly travel to an exit and the population of 12 people will require 9 s to pass through the exit. The travelling time governs and the queuing time is excluded from the RSET. The RSET for the occupants to clear storage area directly to the outside is, RSET = 70 + 30 + 23 = 123 s.

The last occupant in the storage area will take 24 s to travel to an exit through the stairway and the population of 12 people will require 22 s to pass through the exit. The travelling time governs and the queuing time is excluded from the RSET. The RSET for the occupants to clear storage area through stairway is, RSET = 70 + 30 + 24 = 124 s.

B2.5.3 Drive Thru Area

The last occupant in the retail area will take 20 s to travel to an exit and the population of 15 people will require 11 s to pass through the exit. The travelling time governs and the queuing time is excluded from the RSET. The RSET for the occupants in the area is, RSET = 70 + 120 + 20 = 210 s.

B2.5.4 Mezzanine

The last occupant in the mezzanine will take 20 s to travel to the open stairway and the population of 29 people will require 22 s to pass through the open stairway. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants to clear mezzanine to the open stair is, RSET = 70 + 60 + 22 = 152 s.

The last occupant in the mezzanine will take 29 s to travel to an exit through the enclosed stairway and the population of 29 people will require 22 s to pass through the exit. The travelling time governs and the queuing time is excluded from the RSET. The RSET for the occupants to clear mezzanine to the outside through stairway is, RSET = 70 + 60 + 29 = 159 s.

The last occupant in the mezzanine will take 64 s to travel to an exit in the retail area through the open stairway and the population of 615 people will require 246 s to pass through the exit. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants to clear mezzanine to the outside through retail area is, RSET = 70 + 60 + 246 = 376s.

Appendix B3: Drive Thru Fire

The building has the following features related to the egress calculations:

1. The building is a single storey
2. Floor to mezzanine floor is 3.5 m
3. Two stairways are located at the ends of the mezzanine
4. Each stair is 1.2 m wide (clear width)
5. Stair riser are 0.175 m wide and treads are 0.33 m high
6. There is a 0.81 m clear width door at each stairway
7. All final exits are 0.81 m clear width door except there are three 1.0 m clear width doors in the retail area

B3.1 Detection Time

Detection time, 72s, from the sprinkler system was simulated in BRANZFIRE zone modeling for drive thru fire.

B3.2 Pre-movement time

B3.2.1 Retail Area

The pre-movement time, 120s, was taken in the retail area as the occupants are awake, unfamiliar with the building and are remote from in the fire of origin.

B3.2.2 Storage Area

The pre-movement time, 60s, was taken in the storage area as the occupants are awake, familiar with the building and are remote from the fire of origin.

B3.2.3 Drive Thru Area

The pre-movement time, 60s, was taken in the drive thru area as the occupants are awake, unfamiliar with the building and are in the fire of origin.

B3.2.4 Mezzanine

The pre-movement time, 60s, was taken in the mezzanine as the occupants are awake, familiar with the building and are remote from the fire of origin.

B3.3 Travel Time

B3.3.1 Retail Area

NFPA5000 gives an occupant density of 2.8 m^2 per person (0.4 people per square meter). Using the occupant density, the occupant load is 600 people in the retail area. The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied.

The travel distance is measured from the furthest point in the area to the nearest exit, giving the travel distance of 33 m and the horizontal travel time of 28 s.

B3.3.2 Storage Area

NFPA5000 gives an occupant density of 27.9 m^2 per person (0.04 people per square meter). Using the occupant density, the occupant load is 12 people in the storage area. The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied.

The travel distance is measured from the furthest point in the area to the outside of building, giving the travel distance of 27 m and the horizontal travel time of 23 s.

The travel distance is measured from the furthest point in the area to the outside of building through the stairway, giving the travel distance of 28 m and the horizontal travel time of 24 s.

B3.3.3 Drive Thru Area

NFPA5000 gives an occupant density of 27.9 m^2 per person (0.04 people per square meter). Using the occupant density, the occupant load is 15 people in the drive thru area. The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied.

The travel distance is measured from the furthest point in the area to the nearest exit, giving the travel distance of 24 m and the horizontal travel time of 20 s.

B3.3.4 Mezzanine

NFPA5000 gives an occupant density of 9.3 m^2 per person (0.11 people per square meter). Using the occupant density, the occupant load is 29 people in the mezzanine. The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) and the

maximum vertical travel speed (1.00 m/s) are applied.

The travel distance is measured from the furthest point in the mezzanine to the open stairway, giving the horizontal travel distance of 23 m and the travel time of 20 s.

The travel distance is measured from the furthest point in the mezzanine to the enclosed stairway, giving the horizontal travel distance of 34 m and the travel time of 29 s.

The travel distance is measured from the furthest point in the mezzanine to the outside of the building through the retail area, giving the horizontal travel distance of 66 m, the vertical travel distance of 7.5 m, the horizontal travel time of 56 s, the vertical travel time of 8 s, and total traveling time of 64 s.

B3.4 Flow Time and Queuing Time

B3.4.1 Retail Area

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. There are three 1.0 m clear wide doors in the retail area leading to the outside of building. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 2.1 m. Using Equation 7, the actual flow is 2.5 people/s. Assuming half of the occupant from the mezzanine are traveling through the retail area which gives the total occupant of 615 people queuing at the doorway. The queuing time is 246 s from Equation 8.

B3.4.2 Storage Area

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied.

There is a 0.81 m clear wide door in the storage area leading to the outside. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 0.51 m. Using Equation 7, the actual flow is 0.66 people/s. Assuming half of the occupant (6 people) in the storage area are queuing at the doorway. The queuing time is 9 s from Equation 8.

Apart from the direct exit to the outside, occupants can travel to the outside through the enclosed stairway. There is a 0.81 m clear wide door in the stairway leading to the outside.

From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 0.51 m. Using Equation 7, the actual flow is 0.66 people/s. Assuming half of the occupant (6 people) in the storage area and half of the occupant (15 people) in the mezzanine are queuing at the doorway. The queuing time is 22 s from Equation 8.

B3.4.3 Drive Thru Area

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. There are two 0.81 m clear wide doors in the retail area leading to the outside of building. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 1.02 m. Using Equation 7, the actual flow is 1.33 people/s. The total occupant of 15 people queuing at the doorway. The queuing time is 11 s from Equation 8.

B3.4.4 Mezzanine

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied.

There is a 0.81 m clear wide door in the mezzanine leading to each stairway. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 0.51 m. Using Equation 7, the actual flow is 0.66 people/s for each stairway. Assuming half of the occupants (15 people) in the mezzanine is queuing at each stairway. The queuing time is 22 s from Equation 8.

Once the occupants clear the mezzanine, they are either queuing at the enclosed stairway with the storage occupants or queuing at the retail area with the retail occupants. The queuing time in the enclosed stairway is 32 s and the queuing time in the retail area is 246 s.

B3.5 RSET Results

B3.5.1 Retail Area

The last occupant in the retail area will take 28 s to travel to an exit and the population of 615 people will require 246 s to pass through the exit. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants in retail area is, RSET = 72 + 120 + 246 = 438 s.

B3.5.2 Storage Area

The last occupant in the storage area will take 23 s to directly travel to an exit and the population of 12 people will require 9 s to pass through the exit. The travelling time governs and the queuing time is excluded from the RSET. The The RSET for the occupants to clear storage area directly to the outside is, RSET = 72 + 60 + 23 = 155 s.

The last occupant in the storage area will take 24 s to travel to an exit through the stairway and the population of 12 people will require 22 s to pass through the exit. The travelling time governs and the queuing time is excluded from the RSET. The RSET for the occupants to clear storage area through stairway is, RSET = 72 + 60 + 24 = 156 s.

B3.5.3 Drive Thru Area

The last occupant in the retail area will take 20 s to travel to an exit and the population of 15 people will require 11 s to pass through the exit. The travelling time governs and the queuing time is excluded from the RSET. The RSET for the occupants in the area is, RSET = 72 + 60 + 20 = 152 s.

B3.5.4 Mezzanine

The last occupant in the mezzanine will take 20 s to travel to the open stairway and the population of 29 people will require 22 s to pass through the open stairway. The queuing time governs and the travelling time is excluded from the RSET. RSET for the occupants to clear mezzanine to the open stair is, RSET = 72 + 60 + 22 = 154 s.

The last occupant in the mezzanine will take 29 s to travel to an exit through the enclosed stairway and the population of 29 people will require 22 s to pass through the exit. The travelling time governs and the queuing time is excluded from the RSET. The RSET for the occupants to clear mezzanine to the outside through stairway is, RSET = 72 + 60 + 29 = 161 s.

The last occupant in the mezzanine will take 64 s to travel to an exit in the retail area through the open stairway and the population of 615 people will require 246 s to pass through the exit. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants to clear mezzanine to the outside through retail area is, RSET = 72 + 60 + 246 = 378s.

Appendix B4: Mezzanine Fire

The building has the following features related to the egress calculations:

1. The building is a single storey
2. Floor to mezzanine floor is 3.5 m
3. Two stairways are located at the ends of the mezzanine
4. Each stair is 1.2 m wide (clear width)
5. Stair riser are 0.175 m wide and treads are 0.33 m high
6. There is a 0.81 m clear width door at each stairway
7. All final exits are 0.81 m clear width door except there are three 1.0 m clear width doors in the retail area

B4.1 Detection Time

Detection time, 139s, from the sprinkler system was simulated in BRANZFIRE zone modeling for mezzanine fire.

B4.2 Pre-movement time

B4.2.1 Retail Area

The pre-movement time, 120s, was taken in the retail area as the occupants are awake, unfamiliar with the building and are remote from in the fire of origin.

B4.2.2 Storage Area

The pre-movement time, 60s, was taken in the storage area as the occupants are awake, familiar with the building and are remote from the fire of origin.

B4.2.3 Drive Thru Area

The pre-movement time, 60s, was taken in the drive thru area as the occupants are awake, unfamiliar with the building and are remote from the fire of origin.

B4.2.4 Mezzanine

The pre-movement time, 60s, was taken in the mezzanine as the occupants are awake, familiar with the building and are in the fire of origin.

B4.3 Travel Time

B4.3.1 Retail Area

NFPA5000 gives an occupant density of 2.8 m^2 per person (0.4 people per square meter). Using the occupant density, the occupant load is 600 people in the retail area. The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied.

The travel distance is measured from the furthest point in the area to the nearest exit, giving the travel distance of 33 m and the horizontal travel time of 28 s.

B4.3.2 Storage Area

NFPA5000 gives an occupant density of 27.9 m^2 per person (0.04 people per square meter). Using the occupant density, the occupant load is 12 people in the storage area. The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied.

The travel distance is measured from the furthest point in the area to the outside of building, giving the travel distance of 27 m and the horizontal travel time of 23 s.

The travel distance is measured from the furthest point in the area to the outside of building through the stairway, giving the travel distance of 28 m and the horizontal travel time of 24 s.

B4.3.3 Drive Thru Area

NFPA5000 gives an occupant density of 27.9 m^2 per person (0.04 people per square meter). Using the occupant density, the occupant load is 15 people in the drive thru area. The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied.

The travel distance is measured from the furthest point in the area to the nearest exit, giving the travel distance of 24 m and the horizontal travel time of 20 s.

B4.3.4 Mezzanine

NFPA5000 gives an occupant density of 9.3 m^2 per person (0.11 people per square meter). Using the occupant density, the occupant load is 29 people in the mezzanine. The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) and the

maximum vertical travel speed (1.00 m/s) are applied.

The travel distance is measured from the furthest point in the mezzanine to the open stairway, giving the horizontal travel distance of 23 m and the travel time of 20 s.

The travel distance is measured from the furthest point in the mezzanine to the enclosed stairway, giving the horizontal travel distance of 34 m and the travel time of 29 s.

The travel distance is measured from the furthest point in the mezzanine to the outside of the building through the retail area, giving the horizontal travel distance of 66 m, the vertical travel distance of 7.5 m, the horizontal travel time of 56 s, the vertical travel time of 8 s, and total traveling time of 64 s.

B4.4 Flow Time and Queuing Time

B4.4.1 Retail Area

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. There are three 1.0 m clear wide doors in the retail area leading to the outside of building. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 2.1 m. Using Equation 7, the actual flow is 2.5 people/s. Assuming half of the occupant from the mezzanine are traveling through the retail area which gives the total occupant of 615 people queuing at the doorway. The queuing time is 246 s from Equation 8.

B4.4.2 Storage Area

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied.

There is a 0.81 m clear wide door in the storage area leading to the outside. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 0.51 m. Using Equation 7, the actual flow is 0.66 people/s. Assuming half of the occupant (6 people) in the storage area are queuing at the doorway. The queuing time is 9 s from Equation 8.

Apart from the direct exit to the outside, occupants can travel to the outside through the enclosed stairway. There is a 0.81 m clear wide door in the stairway leading to the outside.

From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 0.51 m. Using Equation 7, the actual flow is 0.66 people/s. Assuming half of the occupant (6 people) in the storage area and half of the occupant (15 people) in the mezzanine are queuing at the doorway. The queuing time is 22 s from Equation 8.

B4.4.3 Drive Thru Area

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. There are two 0.81 m clear wide doors in the retail area leading to the outside of building. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 1.02 m. Using Equation 7, the actual flow is 1.33 people/s. The total occupant of 15 people queuing at the doorway. The queuing time is 11 s from Equation 8.

B4.4.4 Mezzanine

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied.

There is a 0.81 m clear wide door in the mezzanine leading to each stairway. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 0.51 m. Using Equation 7, the actual flow is 0.66 people/s for each stairway. Assuming half of the occupants (15 people) in the mezzanine is queuing at each stairway. The queuing time is 22 s from Equation 8.

Once the occupants clear the mezzanine, they are either queuing at the enclosed stairway with the storage occupants or queuing at the retail area with the retail occupants. The queuing time in the enclosed stairway is 32 s and the queuing time in the retail area is 246 s.

B4.5 RSET Results

B4.5.1 Retail Area

The last occupant in the retail area will take 28 s to travel to an exit and the population of 615 people will require 246 s to pass through the exit. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants in retail area is, RSET = 139 + 120 + 246 = 505 s.

B4.5.2 Storage Area

The last occupant in the storage area will take 23 s to directly travel to an exit and the population of 12 people will require 9 s to pass through the exit. The travelling time governs and the queuing time is excluded from the RSET. The RSET for the occupants to clear storage area directly to the outside is, RSET = 139 + 60 + 23 = 222 s.

The last occupant in the storage area will take 24 s to travel to an exit through the stairway and the population of 12 people will require 22 s to pass through the exit. The travelling time governs and the queuing time is excluded from the RSET. The RSET for the occupants to clear storage area through stairway is, RSET = 139 + 60 + 24 = 223 s.

B4.5.3 Drive Thru Area

The last occupant in the retail area will take 20 s to travel to an exit and the population of 15 people will require 11 s to pass through the exit. The travelling time governs and the queuing time is excluded from the RSET. The RSET for the occupants in the area is, RSET = 139 + 60 + 20 = 279 s.

B4.5.4 Mezzanine

The last occupant in the mezzanine will take 20 s to travel to the open stairway and the population of 29 people will require 22 s to pass through the open stairway. The queuing time governs and the travelling time is excluded from the RSET. RSET for the occupants to clear mezzanine to the open stair is, RSET = 139 + 60 + 22 = 191 s.

The last occupant in the mezzanine will take 29 s to travel to an exit through the enclosed stairway and the population of 29 people will require 22 s to pass through the exit. The travelling time governs and the queuing time is excluded from the RSET. The RSET for the occupants to clear mezzanine to the outside through stairway is, RSET = 139 + 60 + 29 = 198 s.

The last occupant in the mezzanine will take 64 s to travel to an exit in the retail area through the open stairway and the population of 615 people will require 246 s to pass through the exit. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants to clear mezzanine to the outside through retail area is, RSET=139+ 60+ 246= 415s.

Appendix B5: Cafeteria Fire

B5.1 Detection Time

Detection time, 141s, from the sprinkler system was simulated in BRANZFIRE zone modeling for cafeteria fire.

B5.2 Pre-movement time

B5.2.1 Cafeteria Area

The pre-movement time, 60s, was taken in the cafeteria area as the occupants are awake, unfamiliar with the building and are in the fire of origin.

B5.2.2 Emergency Area

The pre-movement time, 120s, was taken in the emergency area as the occupants are awake, familiar with the building and are remote from the fire of origin.

B5.2.3 Sleeping Occupants on Floor 4

The pre-movement time, 1800s, was taken in the area as the occupants are asleep, under the care of trained staff and are remote from the fire of origin.

B5.3 Travel Time

B5.3.1 Cafeteria Area

NFPA5000 gives an occupant density of 1.4 m^2 per person (0.72 people per square meter). Using the occupant density, the occupant load is 200 people in the cafeteria area. The occupant density is greater than 0.54 people/m^2 and therefore the maximum horizontal travel speed (1.19 m/s) cannot be applied and Equation 3 in Section 4.6.4 is used to calculate the horizontal travel speed (1.13 m/s).

The travel distance is measured from the furthest point in the area to the nearest exit, giving the travel distance of 30 m and the horizontal travel time of 27 s.

B5.3.2 Emergency Area

NFPA5000 gives an occupant density of 9.3 m^2 per person (0.11 people per square meter). The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied. The travel distance is measured from the furthest point in the area to the outside of building through the main entrance (Exit 5 in Figure A2-9), giving the travel distance of 73 m and the horizontal travel time of 62 s.

B5.3.3 Sleeping Suite on Floor 4

NFPA5000 gives an occupant density of 22.3 m^2 per person (0.05 people per square meter). The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied. The travel distance is measured from the furthest point in the area to the nearest exit, giving the travel distance of 63 m and the horizontal travel time of 53 s.

B5.4 Flow Time and Queuing Time

B5.4.1 Cafeteria Area

The occupant density is greater than 0.54 people/m^2 and the specific flow (0.83 persons/s/m calculated from Equation 5) through a door is applied. There are two 0.81 m clear wide exit doors in the cafeteria area leading to the outside of building. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 1.02 m. Using Equation 7, the actual flow is 0.84 people/s. There are a total occupant of 200 people queuing at the exits. The queuing time is 239 s from Equation 8.

B5.4.2 Emergency Area

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. Assumed half of the occupants from the emergency area egress through the main entrance of the hospital (Exit 5 in Figure A2-9), there are a total of 166 people queuing at the exit. At the exit, there is a 0.83 m clear wide exit door leading to the outside. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 0.31 m. Using Equation 7, the actual flow is 0.69 people/s. The queuing time is 241 s from Equation 8.

B5.4.3 Sleeping Suite on Floor 4

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3

persons/s/m) through a door is applied. The exit stairway has a 0.81 m clear width door leading to the outside of building. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 0.51 m. Using Equation 7, the actual flow is 0.67 people/s. The total occupant of 114 people queuing at the stairway. The queuing time is 171 s from Equation 8.

B5.5 RSET Results

B5.5.1 Cafeteria Area

The last occupant in the cafeteria area will take 27 s to travel to an exit and the population of 200 people will require 239 s to pass through the exit. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants to clear the building is, RSET = 141 + 60 + 239 = 440 s.

B5.5.2 Emergency Area

The last occupant in the emergency area will take 62 s to travel to the main entrance (Exit 5 in Figure A2-9) through the common corridor and the population of 166 people will require 241 s to pass through the exit. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants to clear the building is, RSET = 141 + 120 + 241 = 502 s.

B5.5.3 Sleeping Suite on Floor 4

The last occupant in the sleeping suite on floor 4 will take 53 s to travel to the exit stairway and the population of 114 people will require 171 s to pass through the exit. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants to clear the building is, RSET = 141 + 1800 + 171 = 2131 s.

Appendix B6: Physiotherapy Fire

B6.1 Detection Time

Detection time, 153s, from the sprinkler system was simulated in BRANZFIRE zone modeling for physiotherapy fire.

B6.2 Pre-movement time

B6.2.1 Physiotherapy Area

The pre-movement time, 60s, was taken in the physiotherapy area as the occupants are awake, unfamiliar with the building and are in the fire of origin.

B6.2.2 Emergency Area

The pre-movement time, 120s, was taken in the emergency area as the occupants are awake, familiar with the building and are remote from the fire of origin.

B6.2.3 Sleeping Occupants on Floor 4

The pre-movement time, 1800s, was taken in the area as the occupants are asleep, under the care of trained staff and are remote from the fire of origin.

B6.3 Travel Time

B6.3.1 Physiotherapy Area

NFPA5000 gives an occupant density of 9.3 m^2 per person (0.1 people per square meter). Using the occupant density, the occupant load is 68 people in the physiotherapy area. The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied.

The travel distance is measured from the furthest point in the area to the common corridor or to the outside of building, giving the travel distance of 33 m and the horizontal travel time of 28 s.

The travel distance is measured from the furthest point in the area to the main entrance, giving the travel distance of 68 m and the horizontal travel time of 56 s.

B6.3.2 Emergency Area

NFPA5000 gives an occupant density of 9.3 m^2 per person (0.11 people per square meter). The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied. The travel distance is measured from the furthest point in the area to the outside of building through the main entrance (Exit 5 in Figure A2-9), giving the travel distance of 73 m and the horizontal travel time of 62 s.

B6.3.3 Sleeping Suite on Floor 4

NFPA5000 gives an occupant density of 22.3 m^2 per person (0.05 people per square meter). The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied. The travel distance is measured from the furthest point in the area to the nearest exit, giving the travel distance of 63 m and the horizontal travel time of 53 s.

B6.4 Flow Time and Queuing Time

B6.4.1 Physiotherapy Area

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. There is a 0.81 m clear wide exit door leading to the outside of building and a 0.81 m clear wide door to the common corridor leading to the outside of building through the main entrance. From Table 4-11 and Equation 6 in Section 4.6.5, the total effective width is 1.02 m. Using Equation 7, the actual flow is 1.33 people/s. There is a total occupant of 68 people queuing at the doors. The queuing time is 51 s from Equation 8.

Assumed half of the occupants from the physiotherapy area travel through the main entrance, there are a total of 166 people queuing at the exit. At the exit, there is a 0.83 m clear wide exit door leading to the outside. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 0.31 m. Using Equation 7, the actual flow is 0.69 people/s. The queuing time is 241 s from Equation 8.

B6.4.2 Emergency Area

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. Assumed half of the occupants from the emergency area egress through the main entrance of the hospital (Exit 5 in Figure A2-9), there are a total of 166 people queuing at the exit. At the exit, there is a 0.83 m clear wide exit door leading to the outside. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 0.51 m. Using Equation 7, the actual flow is 0.69 people/s. The queuing time is 241 s from Equation 8.

B6.4.3 Sleeping Suite on Floor 4

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. The exit stairway has a 0.81 m clear width door leading to the outside of building. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 0.51 m. Using Equation 7, the actual flow is 0.67 people/s. The total occupant of 114 people queuing at the stairway. The queuing time is 171 s from Equation 8.

B6.5 RSET Results

B6.5.1 Physiotherapy Area

The last occupant in the physiotherapy area will take 28 s to travel to the common corridor or the outside of building and the population of 68 people will require 51 s to pass through the doors. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants in area to the corridor is, RSET = 153 + 60 + 51 = 264 s.

The last occupant in the physiotherapy area will take 56 s to travel to the main entrance (Exit 5 in Figure A2-9) through the common corridor and the population of 166 people will require 241 s to pass through the exit. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants to clear the building is, RSET = 153 + 60 + 241 = 454 s.

B6.5.2 Emergency Area

The last occupant in the emergency area will take 62 s to travel to the main entrance (Exit 5 in Figure A2-9) through the common corridor and the population of 166 people will require 241 s to pass through the exit. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants to clear the building is, RSET = 153 + 120 + 241 = 514 s.

B6.5.3 Sleeping Suite on Floor 4

The last occupant in the sleeping suite on floor 4 will take 53 s to travel to the exit stairway and the population of 114 people will require 171 s to pass through the exit. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants to clear the building is, RSET = 153 + 1800 + 171 = 2124 s.

Appendix B7: Laboratory Fire

B7.1 Detection Time

Detection time, 160s, from the sprinkler system was simulated in BRANZFIRE zone modeling for laboratory fire.

B7.2 Pre-movement time

B7.2.1 Laboratory Area

The pre-movement time, 30s, was taken in the laboratory area as the occupants are awake, familiar with the building and are in the fire of origin.

B7.2.2 Sleeping Occupants on Floor 2

The pre-movement time, 1800s, was taken in the area as the occupants are asleep, under the care of trained staff and are remote from the fire of origin.

B7.2.3 Sleeping Occupants on Floor 4

The pre-movement time, 1800s, was taken in the area as the occupants are asleep, under the care of trained staff and are remote from the fire of origin.

B7.3 Travel Time

B7.3.1 Laboratory Area

NFPA5000 gives an occupant density of 22.3 m^2 per person (0.04 people per square meter). Using the occupant density, the occupant load is 96 people in the laboratory area. The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied.

The travel distance is measured from the furthest point in the area to the common corridor, giving the travel distance of 33 m and the horizontal travel time of 28 s.

The travel distance is measured from the furthest point in the area to the exit stairway, giving the travel distance of 58 m and the horizontal travel time of 49 s.

B7.3.2 Sleeping Suite on Floor 2

NFPA5000 gives an occupant density of 22.3 m^2 per person (0.05 people per square meter). The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied. The travel distance is measured from the furthest point in the area to the nearest exit, giving the travel distance of 56 m and the horizontal travel time of 47 s.

B7.3.3 Sleeping Suite on Floor 4

NFPA5000 gives an occupant density of 22.3 m^2 per person (0.05 people per square meter). The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied. The travel distance is measured from the furthest point in the area to the nearest exit, giving the travel distance of 63 m and the horizontal travel time of 53 s.

B7.4 Flow Time and Queuing Time

B7.4.1 Laboratory Area

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. There are two 0.81 m clear wide exit door leading to the common corridor. From Table 4-11 and Equation 6 in Section 4.6.5, the total effective width is 1.02 m. Using Equation 7, the actual flow is 1.33 people/s. There is a total occupant of 96 people queuing at the doors. The queuing time is 72 s from Equation 8.

Assumed half of the occupants from the laboratory area travel through the exit stairway, there are a total of 59 people queuing at the exit stairway in the common area. At the exit, there is a 0.81 m clear wide exit door. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 0.51 m. Using Equation 7, the actual flow is 0.66 people/s. The queuing time is 89 s from Equation 8.

B7.4.2 Sleeping Suite on Floor 2

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. The exit stairway has a 0.81 m clear width door leading to the outside of building. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 0.51 m. Using Equation 7, the actual flow is 0.67 people/s. The total occupant of 40 people queuing at the stairway. The queuing time is 60 s from Equation 8.

B7.4.3 Sleeping Suite on Floor 4

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. The exit stairway has a 0.81 m clear width door leading to the outside of building. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 0.51 m. Using Equation 7, the actual flow is 0.67 people/s. The total occupant of 114 people queuing at the stairway. The queuing time is 171 s from Equation 8.

B7.5 RSET Results

B7.5.1 Laboratory Area

The last occupant in the laboratory area will take 28 s to travel to the common corridor and the population of 96 people will require 72 s to pass through the doors. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants to clear the Laboratory to the corridor is, RSET = 160 + 30 + 72 = 262 s.

The last occupant in the laboratory area will take 49 s to travel to the exit stairway through the common corridor and the population of 59 people will require 89 s to pass through the exit stairway. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants to clear floor 2 to the fire isolated stairway is, RSET = 160 + 30 + 89 = 279 s.

B7.5.2 Sleeping Suite on Floor 2

The last occupant in the sleeping suite on floor 2 will take 47 s to travel to the exit stairway and the population of 40 people will require 60 s to pass through the exit. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants to clear floor 2 to the fire isolated stairway is, RSET = 160 + 1800 + 60 = 2020 s.

B7.5.3 Sleeping Suite on Floor 4

The last occupant in the sleeping suite on floor 4 will take 53 s to travel to the exit stairway and the population of 114 people will require 171 s to pass through the exit. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants to clear the building is, RSET = 160 + 1800 + 171 = 2131 s.

Appendix B8: Hostel Fire

B8.1 Detection Time

Detection time, 59s, from the smoke detection system was simulated in BRANZFIRE zone modeling for hostel fire.

B8.2 Pre-movement time

B8.2.1 Hostel Area

The pre-movement time, 60s, was taken in the laboratory area as the occupants are asleep, unfamiliar with the building and are in the fire of origin.

B8.2.2 Sleeping Occupants on Floor 3

The pre-movement time, 1800s, was taken in the area as the occupants are asleep, under the care of trained staff and are remote from the fire of origin.

B8.2.3 Sleeping Occupants on Floor 4

The pre-movement time, 1800s, was taken in the area as the occupants are asleep, under the care of trained staff and are remote from the fire of origin.

B8.3 Travel Time

B8.3.1 Hostel Area

NFPA5000 gives an occupant density of 22.3 m^2 per person (0.04 people per square meter). Using the occupant density, the occupant load is 24 people in the hostel area. The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied.

The travel distance is measured from the furthest point in the area to the common corridor, giving the travel distance of 29 m and the horizontal travel time of 24 s.

The travel distance is measured from the furthest point in the area to the exit stairway, giving the travel distance of 60 m and the horizontal travel time of 50 s.

B8.3.2 Sleeping Suite on Floor 3

NFPA5000 gives an occupant density of 22.3 m^2 per person (0.05 people per square meter). The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied. The travel distance is measured from the furthest point in the area to the nearest exit, giving the travel distance of 56 m and the horizontal travel time of 47 s.

B8.3.3 Sleeping Suite on Floor 4

NFPA5000 gives an occupant density of 22.3 m^2 per person (0.05 people per square meter). The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied. The travel distance is measured from the furthest point in the area to the nearest exit, giving the travel distance of 63 m and the horizontal travel time of 53 s.

B8.4 Flow Time and Queuing Time

B8.4.1 Hostel Area

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. There are two 0.81 m clear wide exit door leading to the common corridor. From Table 4-11 and Equation 6 in Section 4.6.5, the total effective width is 1.02 m. Using Equation 7, the actual flow is 1.33 people/s. There is a total occupant of 24 people queuing at the doors. The queuing time is 18 s from Equation 8.

Assumed half of the occupants from the hostel area travel through the exit stairway, there are a total of 21 people queuing at the exit stairway in the common area. At the exit, there is a 0.81 m clear wide exit door. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 0.51 m. Using Equation 7, the actual flow is 0.66 people/s. The queuing time is 32 s from Equation 8.

B8.4.2 Sleeping Suite on Floor 3

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. The exit stairway has a 0.81 m clear width door leading to the outside of building. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 0.51 m. Using Equation 7, the actual flow is 0.67 people/s. The total occupant of 45 people queuing at the stairway. The queuing time is 68 s from Equation 8.

B8.4.3 Sleeping Suite on Floor 4

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. The exit stairway has a 0.81 m clear width door leading to the outside of building. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 0.51 m. Using Equation 7, the actual flow is 0.67 people/s. The total occupant of 114 people queuing at the stairway. The queuing time is 171 s from Equation 8.

B8.5 RSET Results

B8.5.1 Hostel Area

The last occupant in the hostel area will take 24 s to travel to the common corridor and the population of 24 people will require 18 s to pass through the doors. The travelling time governs and the queuing time is excluded from the RSET. The RSET for the occupants to clear hostel to the corridor is, RSET = 59 + 60 + 24 = 143 s.

The last occupant in the hostel area will take 50 s to travel to the exit stairway through the common corridor and the population of 21 people will require 18 s to pass through the exit stairway. The travelling time governs and the queuing time is excluded from the RSET. The RSET for the occupants to clear floor 3 to the fire isolated stairway is, RSET = 59 + 60 + 50 = 169 s.

B8.5.2 Sleeping Suite on Floor 3

The last occupant in the sleeping suite on floor 2 will take 47 s to travel to the exit stairway and the population of 45 people will require 68 s to pass through the exit. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants to clear floor 3 to the fire isolated stairway is, RSET = 59 + 1800 + 68 = 1927 s.

B8.5.3 Sleeping Suite on Floor 4

The last occupant in the sleeping suite on floor 4 will take 53 s to travel to the exit stairway and the population of 114 people will require 171 s to pass through the exit. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants to clear the building is, RSET = 59 + 1800 + 171 = 2030 s.

Appendix B9: Anchor Building Fire

B9.1 Detection Time

Detection time, 244s, from the sprinkler system was simulated in BRANZFIRE zone modeling for anchor building-3 fire on floor 3.

B9.2 Pre-movement time

B9.2.1 Anchor Building – 3

The pre-movement time, 60s, was taken in the anchor building – 3 as the occupants are awake, unfamiliar with the building and are in the fire of origin.

B9.2.2 Tenants on Floor 3

The pre-movement time, 120s, was taken in the mall area as the occupants are awake, unfamiliar with the building and are remote from the fire of origin.

B9.2.3 Car park on Floor 4

The pre-movement time, 120s, was taken in the car park as the occupants are awake, unfamiliar with the building and are remote from the fire of origin.

B9.3 Travel Time

B9.3.1 Anchor Building – 3

NFPA5000 gives an occupant density of 2.8 m^2 per person (0.36 people per square meter). Using the occupant density, the occupant load is 465 people in the anchor building – 3. The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied. The travel distance is measured from the furthest point in the area to the exit stairway, giving the travel distance of 70 m and the horizontal travel time of 59 s.

B9.3.2 Tenants on Floor 3

NFPA5000 gives an occupant density of 2.8 m^2 per person (0.36 people per square meter). The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied. The travel distance is measured from the furthest point in the area to the exit stairway, giving the travel distance of 125 m and the horizontal travel time of 106 s.

B9.3.3 Car park on Floor 4

NFPA5000 gives an occupant density of 46.5 m^2 per person (0.03 people per square meter). The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied. The travel distance is measured from the furthest point in the area to the exit stairway, giving the travel distance of 112 m and the horizontal travel time of 95 s.

B9.4 Flow Time and Queuing Time

B9.4.1 Anchor Building – 3

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. There are three exit stairways and each exit stairway has a 0.81 m clear width door leading to the outside of building. From Table 4-11 and Equation 6 in Section 4.6.5, the total effective width is 2.43 m. Using Equation 7, the actual flow is 1.99 people/s. There is a total occupant of 465 people queuing at the doors. The queuing time is 234 s from Equation 8.

B9.4.2 Tenants on Floor 3

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. There are seven exit stairways and the total clear width of all of the exit stairways is 18 m. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 15.9 m. Using Equation 7, the actual flow is 11.67 people/s. The total occupant of 3585 people queuing at the stairway. The queuing time is 308 s from Equation 8.

B9.4.3 Car park on Floor 4

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. There are four exit stairways and each exit stairway has a 0.81 m clear width door leading to the outside of building From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 2.04 m. Using Equation 7, the actual flow is 2.66 people/s. The total occupant of 467 people queuing at the stairway. The queuing time is 176 s from Equation 8.

B9.5 RSET Results

B9.5.1 Anchor Building – 3

The last occupant in the anchor building – 3 will take 59 s to travel to the exit stairway and the population of 465 people will require 234 s to pass through the doors. The queuing time governs and the travel time is excluded from the RSET. The RSET for the occupants to clear the area to the fire isolated stairway is, RSET = 244 + 60 + 234 = 538 s.

B9.5.2 Tenants on Floor 3

The last occupant in the mall area on floor 3 will take 106 s to travel to the exit stairway and the population of 3585 people will require 308 s to pass through the exit. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants to clear the communicating space to the fire isolated stairway is, RSET = 244 + 120 + 308 = 672 s.

B9.5.3 Car park on Floor 4

The last occupant in the car park on floor 4 will take 95 s to travel to the exit stairway and the population of 467 people will require 598 s to pass through the exit. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants to clear the building is, RSET = 244 + 120 + 176 = 540 s.

Appendix B10: Restaurant Fire

B10.1 Detection Time

Detection time, 200s, from the sprinkler system was simulated in BRANZFIRE zone modeling for restaurant fire on floor 3.

B10.2 Pre-movement time

B10.2.1 Restaurant on Floor 3

The pre-movement time, 60s, was taken in the anchor building – 3 as the occupants are awake, unfamiliar with the building and are in the fire of origin.

B10.2.2 Tenants on Floor 3

The pre-movement time, 120s, was taken in the mall area as the occupants are awake, unfamiliar with the building and are remote from the fire of origin.

B10.2.3 Car park on Floor 4

The pre-movement time, 120s, was taken in the car park as the occupants are awake, unfamiliar with the building and are remote from the fire of origin.

B10.3 Travel Time

B10.3.1 Restaurant on Floor 3

The owner of the restaurant specified the occupant load of 200 people in the area of 320 m^2, which is equivalence to an occupant density of 1.6 m^2 per person (0.63 people per square meter). The occupant density is greater than 0.54 people/m^2 and therefore the maximum horizontal travel speed (1.19 m/s) cannot be applied and Equation 3 in Section 4.6.4 is used to calculate the horizontal travel speed (1.17 m/s). The travel distance is measured from the furthest point in the area to the door leading to the mall area, giving the travel distance of 30 m and the horizontal travel time of 26 s.

B10.3.2 Tenants on Floor 3

NFPA5000 gives an occupant density of 2.8 m^2 per person (0.36 people per square meter). The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied. The travel distance is measured from the furthest point in the area to the exit stairway, giving the travel distance of 125 m and the horizontal travel time of 106 s.

B10.3.3 Car park on Floor 4

NFPA5000 gives an occupant density of 46.5 m^2 per person (0.03 people per square meter). The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied. The travel distance is measured from the furthest point in the area to the exit stairway, giving the travel distance of 112 m and the horizontal travel time of 95 s.

B10.4 Flow Time and Queuing Time

B10.4.1 Restaurant on Floor 3

The occupant density is greater than 0.54 people/m^2 and the specific flow (0.74 persons/s/m calculated from Equation 5) through a door is applied. There are two doors and each door has a 0.81 m clear width door leading to the mall area. From Table 4-11 and Equation 6 in Section 4.6.5, the total effective width is 1.02 m. Using Equation 7, the actual flow is 0.76 people/s. There is a total occupant of 200 people queuing at the doors. The queuing time is 264 s from Equation 8.

B10.4.2 Tenants on Floor 3

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. There are seven exit stairways and the total clear width of all of the exit stairways is 18 m. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 15.9 m. Using Equation 7, the actual flow is 11.67 people/s. The total occupant of 3585 people queuing at the stairway. The queuing time is 308 s from Equation 8.

B10.4.3 Car park on Floor 4

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. There are four exit stairways and each exit stairway has a 0.81 m clear width door leading to the outside of building From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 2.04 m. Using Equation 7, the actual flow is 2.66 people/s.

The total occupant of 467 people queuing at the stairway. The queuing time is 176 s from Equation 8.

B10.5 RSET Results

B10.5.1 Restaurant on Floor 3

The last occupant in the restaurant will take 26 s to travel to the doors and the population of 200 people will require 234 s to pass through the doors. The queuing time governs and the travel time is excluded from the RSET. The RSET for the occupants in area is, RSET = 200 + 60 + 246 = 524 s.

B10.5.2 Tenants on Floor 3

The last occupant in the mall area on floor 3 will take 106 s to travel to the exit stairway and the population of 3585 people will require 308 s to pass through the exit. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants to clear the communicating space to the fire isolated stairway is, RSET = 200 + 120 + 308 = 628 s.

B10.5.3 Car park on Floor 4

The last occupant in the car park on floor 4 will take 95 s to travel to the exit stairway and the population of 467 people will require 176 s to pass through the exit. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants to clear the building is, RSET = 200 + 120 + 176 = 496 s.

Appendix B11: Small Shop Fire

B11.1 Detection Time

Detection time, 194s, from the sprinkler system was simulated in BRANZFIRE zone modeling for small shop fire on floor 3.

B11.2 Pre-movement time

B11.2.1 Small shop on Floor 3

The pre-movement time, 60s, was taken in the small shop as the occupants are awake, unfamiliar with the building and are in the fire of origin.

B11.2.2 Tenants on Floor 3

The pre-movement time, 120s, was taken in the mall area as the occupants are awake, unfamiliar with the building and are remote from the fire of origin.

B11.2.3 Car park on Floor 4

The pre-movement time, 120s, was taken in the car park as the occupants are awake, unfamiliar with the building and are remote from the fire of origin.

B11.3 Travel Time

B11.3.1 Small shop on Floor 3

NFPA5000 gives an occupant density of 2.8 m^2 per person (0.36 people per square meter). The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied. The travel distance is measured from the furthest point in the area to the door leading to the mall area, giving the travel distance of 22 m and the horizontal travel time of 19 s.

B11.3.2 Tenants on Floor 3

NFPA5000 gives an occupant density of 2.8 m^2 per person (0.36 people per square meter). The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied. The travel distance is measured from the furthest point in the area to the exit stairway, giving the travel distance of 125 m and the horizontal travel time of 106 s.

B11.3.3 Car park on Floor 4

NFPA5000 gives an occupant density of 46.5 m^2 per person (0.03 people per square meter). The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied. The travel distance is measured from the furthest point in the area to the exit stairway, giving the travel distance of 112 m and the horizontal travel time of 95 s.

B11.4 Flow Time and Queuing Time

B11.4.1 Small shop on Floor 3

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. There is a 0.81 m clear width doors leading to the mall area. From Table 4-11 and Equation 6 in Section 4.6.5, the total effective width is 0.51 m. Using Equation 7, the actual flow is 0.67 people/s. There is a total occupant of 88 people queuing at the doors. The queuing time is 132 s from Equation 8.

B11.4.2 Tenants on Floor 3

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. There are seven exit stairways and the total clear width of all of the exit stairways is 18 m. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 15.9 m. Using Equation 7, the actual flow is 11.67 people/s. The total occupant of 3585 people queuing at the stairway. The queuing time is 308 s from Equation 8.

B11.4.3 Car park on Floor 4

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. There are four exit stairways and each exit stairway has a 0.81 m clear width door leading to the outside of building From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 2.04 m. Using Equation 7, the actual flow is 2.66 people/s. The total occupant of 467 people queuing at the stairway. The queuing time is 176 s from Equation 8.

B11.5 RSET Results

B11.5.1 Small shop on Floor 3

The last occupant in the small shop will take 19 s to travel to the door and the population of 88 people will require 132 s to pass through the door. The queuing time governs and the travel time is excluded from the RSET. The RSET for the occupants in the area is, RSET = 194 + 60 + 132 = 386 s.

B11.5.2 Tenants on Floor 3

The last occupant in the mall area on floor 3 will take 106 s to travel to the exit stairway and the population of 3585 people will require 308 s to pass through the exit. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants to clear the communicating space to the fire isolated stairway is, RSET = 194 + 120 + 308 = 622 s.

B11.5.3 Car park on Floor 4

The last occupant in the car park on floor 4 will take 95 s to travel to the exit stairway and the population of 467 people will require 176 s to pass through the exit. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants to clear the building is, RSET = 194 + 120 + 176 = 490 s.

Appendix B12: Communicating Space Fire

B12.1 Detection Time

Detection time, 467s, from the sprinkler system was simulated in BRANZFIRE zone modeling for communicating space fire on floor 3.

B12.2 Pre-movement time

B12.2.1 Anchor Building – 3 on Floor 3

The pre-movement time, 120s, was taken in the anchor building – 3 as the occupants are awake, unfamiliar with the building and are remote from the fire of origin.

B12.2.2 Tenants on Floor 3

The pre-movement time, 120s, was taken in the mall area as the occupants are awake, unfamiliar with the building and are remote from the fire of origin.

B12.2.3 Car park on Floor 4

The pre-movement time, 120s, was taken in the car park as the occupants are awake, unfamiliar with the building and are remote from the fire of origin.

B12.3 Travel Time

B12.3.1 Anchor Building – 3 on Floor 3

NFPA5000 gives an occupant density of 2.8 m^2 per person (0.36 people per square meter). Using the occupant density, the occupant load is 465 people in the anchor building – 3. The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied. The travel distance is measured from the furthest point in the area to the exit stairway, giving the travel distance of 70 m and the horizontal travel time of 59 s.

B12.3.2 Tenants on Floor 3

NFPA5000 gives an occupant density of 2.8 m^2 per person (0.36 people per square meter). The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied. The travel distance is measured from the furthest point in the area to the exit stairway, giving the travel distance of 125 m and the horizontal travel time of 106 s.

B12.3.3 Car park on Floor 4

NFPA5000 gives an occupant density of 46.5 m^2 per person (0.03 people per square meter). The occupant density is less than 0.54 people/m^2 and the maximum horizontal travel speed (1.19 m/s) is applied. The travel distance is measured from the furthest point in the area to the exit stairway, giving the travel distance of 112 m and the horizontal travel time of 95 s.

B12.4 Flow Time and Queuing Time

B12.4.1 Anchor Building – 3 on Floor 3

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. There are three exit stairways and each exit stairway has a 0.81 m clear width door leading to the outside of building. From Table 4-11 and Equation 6 in Section 4.6.5, the total effective width is 2.43 m. Using Equation 7, the actual flow is 1.99 people/s. There is a total occupant of 465 people queuing at the doors. The queuing time is 234 s from Equation 8.

B12.4.2 Tenants on Floor 3

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. There are seven exit stairways and the total clear width of all of the exit stairways is 18 m. From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 15.9 m. Using Equation 7, the actual flow is 11.67 people/s. The total occupant of 3585 people queuing at the stairway. The queuing time is 308 s from Equation 8.

B12.4.3 Car park on Floor 4

The occupant density is less than 0.54 people/m^2 and the maximum specific flow (1.3 persons/s/m) through a door is applied. There are four exit stairways and each exit stairway has a 0.81 m clear width door leading to the outside of building From Table 4-11 and Equation 6 in Section 4.6.5, the effective width is 2.04 m. Using Equation 7, the actual flow is 2.66 people/s. The total occupant of 467 people queuing at the stairway. The queuing time is 176 s from Equation 8.

B12.5 RSET Results

B12.5.1 Anchor Building – 3 on Floor 3

The last occupant in the anchor building – 3 will take 59 s to travel to the exit stairway and the population of 465 people will require 234 s to pass through the doors. The queuing time governs and the travel time is excluded from the RSET. The RSET for the occupants to clear the area to the fire isolated stairway is, RSET = 467 + 120 + 234 = 821 s.

B12.5.2 Tenants on Floor 3

The last occupant in the mall area on floor 3 will take 106 s to travel to the exit stairway and the population of 3585 people will require 308 s to pass through the exit. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants to clear the communicating space to the fire isolated stairway is, RSET = 467 + 120 + 308 = 895 s.

B12.5.3 Car park on Floor 4

The last occupant in the car park on floor 4 will take 95 s to travel to the exit stairway and the population of 467 people will require 176 s to pass through the exit. The queuing time governs and the travelling time is excluded from the RSET. The RSET for the occupants to clear the building is, RSET = 467 + 120 + 176 = 763 s.

Appendix C: Overall summary of DFS1 results in the room of fire origin

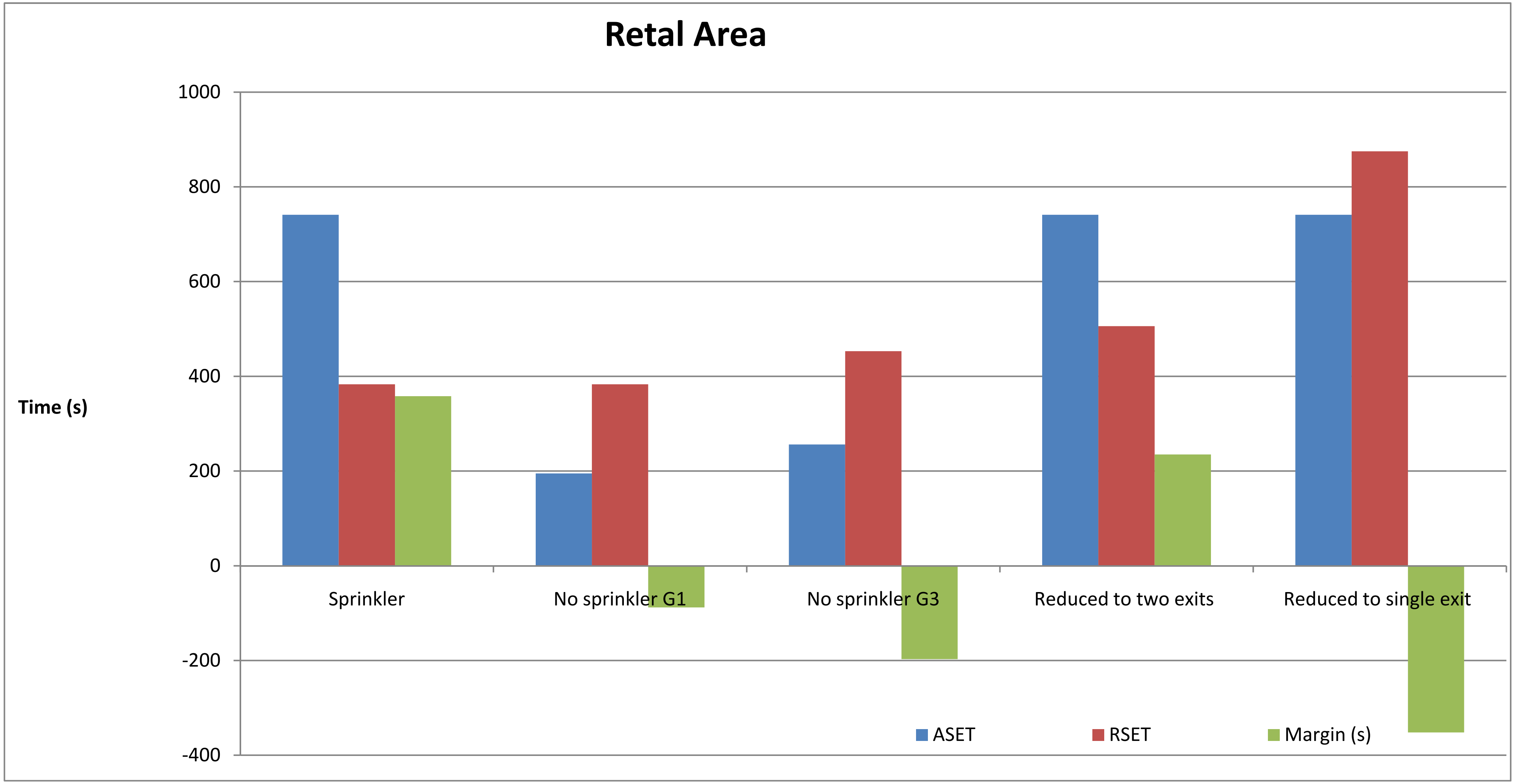
Three case study buildings designed in accordance with the prescriptive requirements in NFPA5000 were explored in chapters 4 to 6. The buildings designed to be substantially altered from the NFPA5000 prescriptive requirements were further investigated in chapter 7. A brief description of the analyses is shown in the following table. The overall results of DFS1 in the room of fire origin for retail warehouse, hospital and shopping mall were summarised in Appendix C1, C2 and C3 respectively.

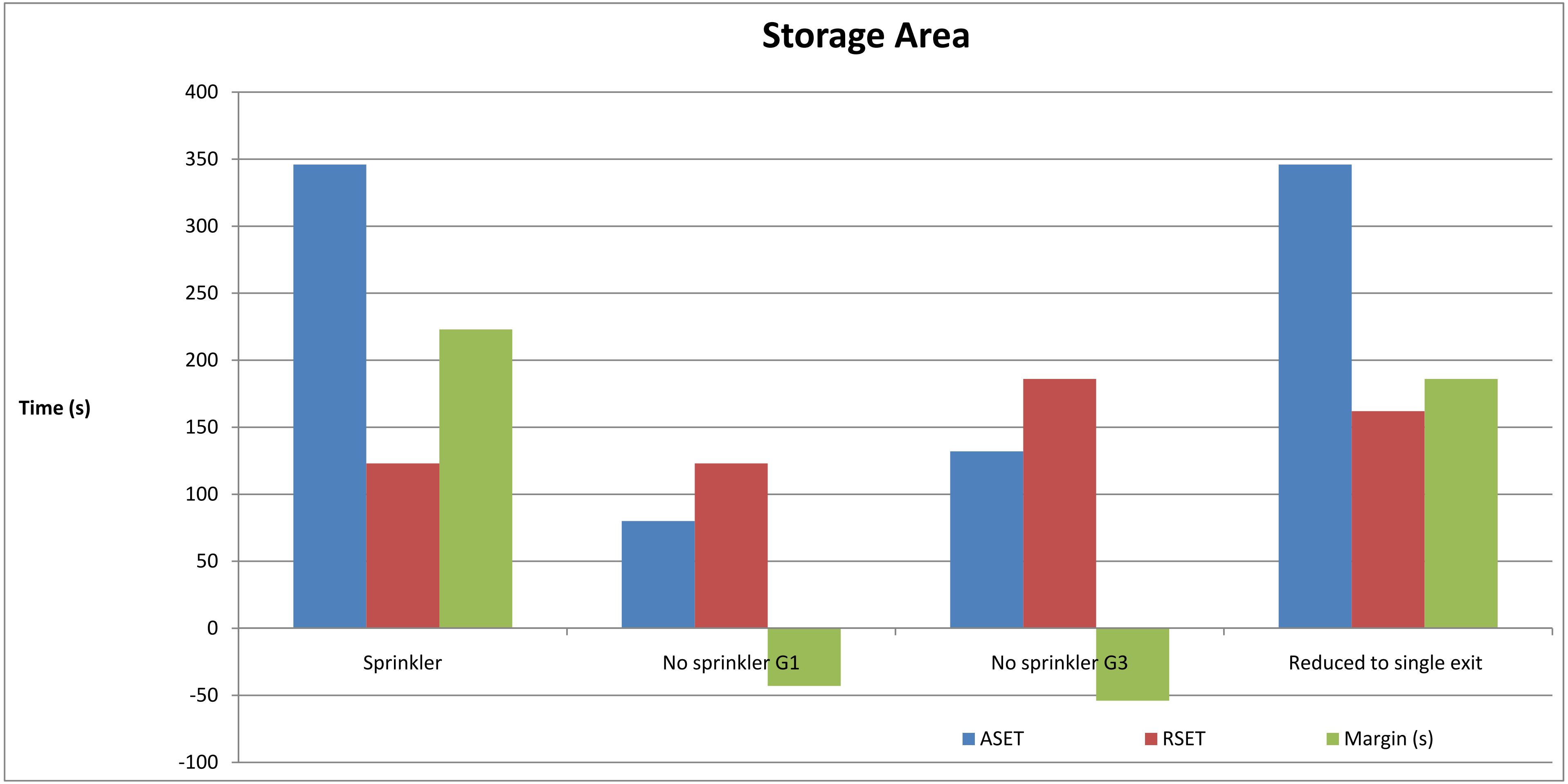
Event	NFPA5000 Compliance Building	Description
Sprinkler	Yes	Automatic sprinkler system was modelled
No sprinkler G1	No	Automatic sprinkler system was not modelled and the design fire was assumed to grow as a rack storage Group 1 t^3
No sprinkler G3	No	Automatic sprinkler system was not modelled and the design fire was assumed to grow as a rack storage Group 3 t^3
No sprinkler	No	Automatic sprinkler system was not modelled and the design fire was assumed to grow as fast t^2
No smoke detector	No	Smoke detection system was not modelled and the design fire was assumed to grow as fast t^2
No fire/smoke separations	No	All interior walls were assumed to have leakage areas and all doors were modelled to be open
Reduced to six exits	No	Six exits remained in the room of fire origin
Reduced to five exits	No	Five exits remained in the room of fire origin
Reduced to two exits	No	Two exits remained in the room of fire origin
Reduced to single exit	No	Single exit remained in the room of fire origin

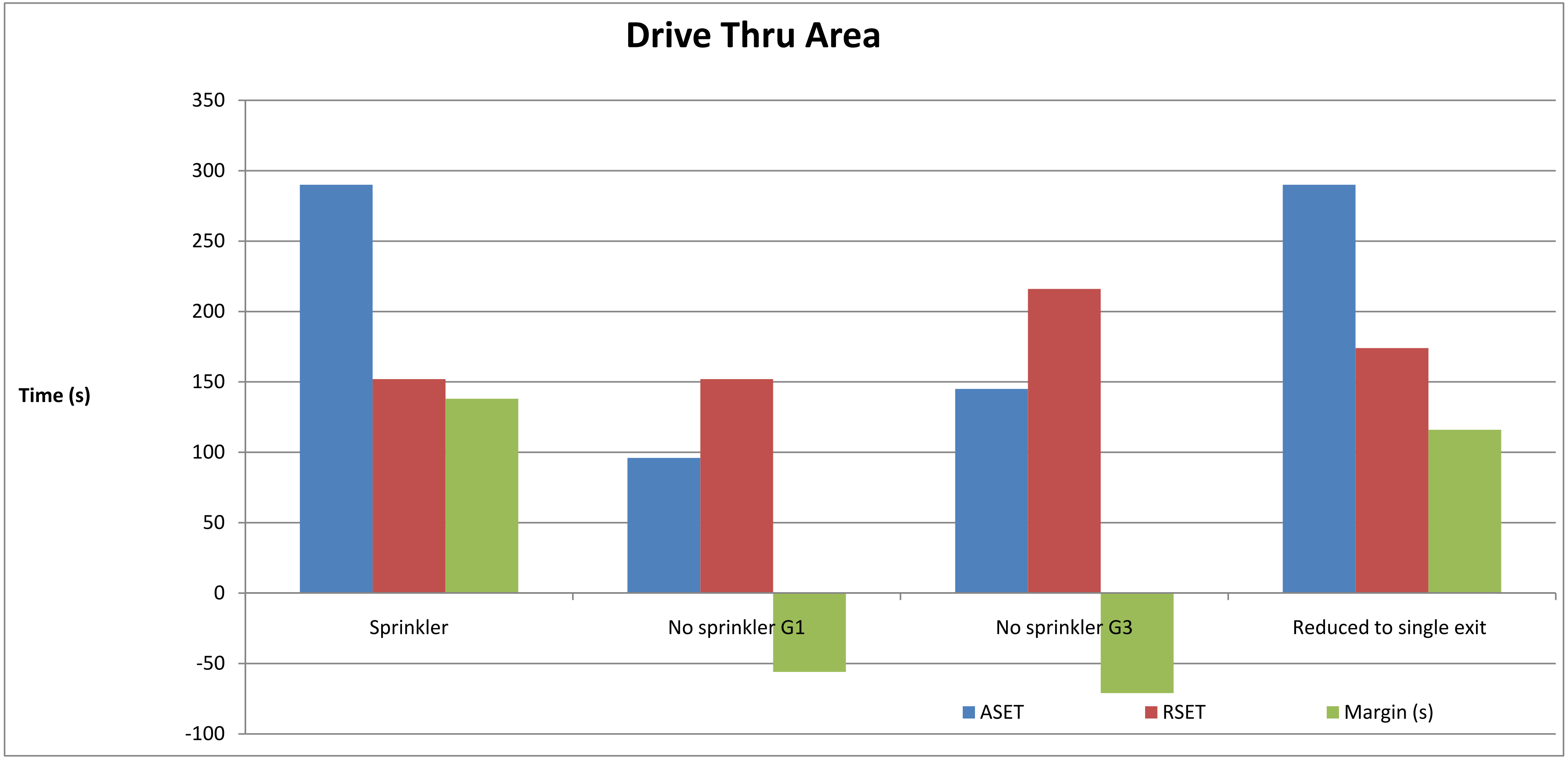
Appendix C1: Case Study Building One (Retail Warehouse)

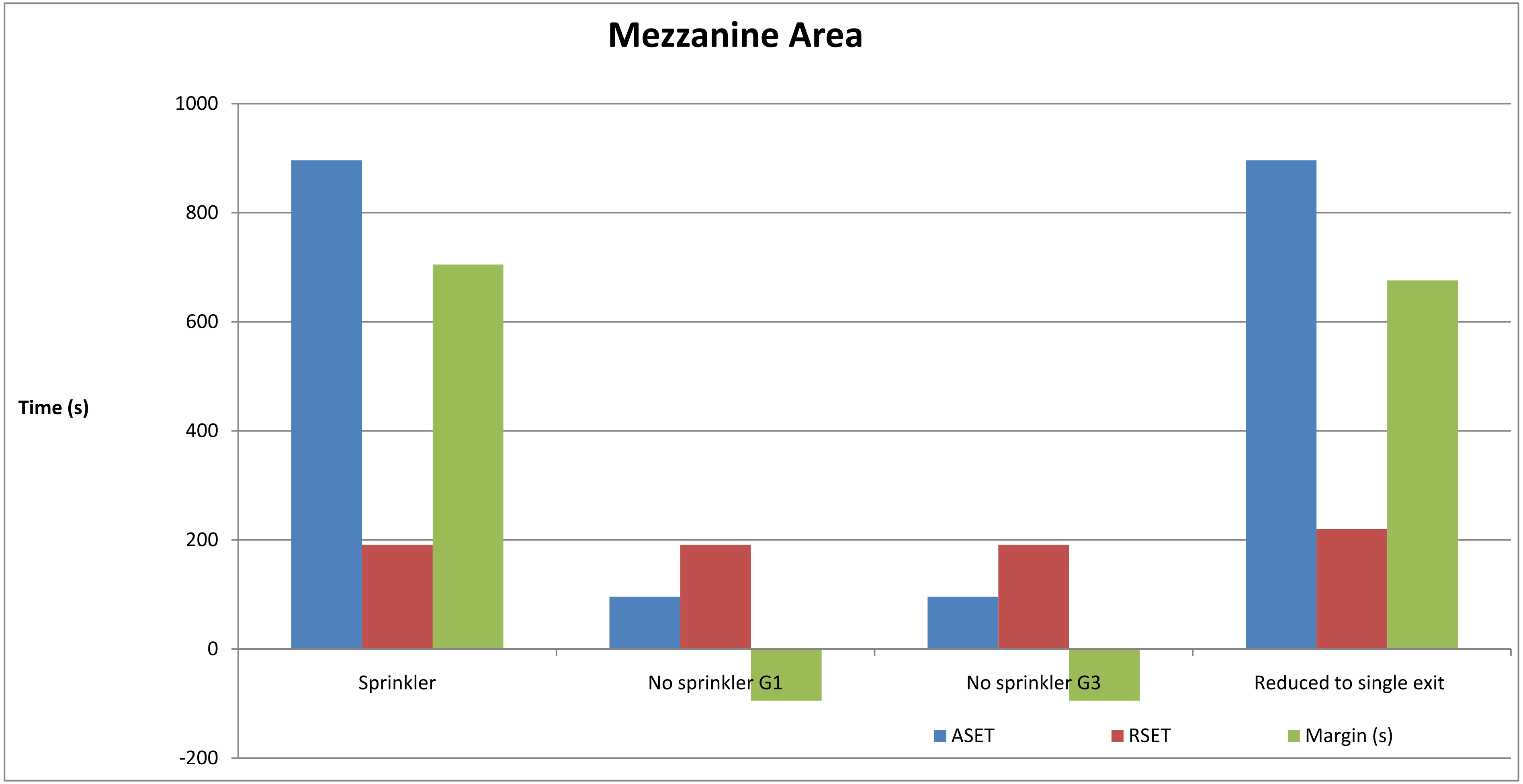
Location	Output	Sprinkler	No sprinkler G1	No sprinkler G3	Reduced to two exits	Reduced to single exit
Fire Located in Retail Area						
Retail area	FED (CO)	741	741	821	741	741
	FED (thermal)	219	219	285	219	219
	Visibility	195	195	256	195	195
	ASET (s)	741	195	256	741	741
	Detection Time	77	77	147	77	77
	RSET (s)	383	383	453	506	875
	Margin (s)	358	-88	-197	235	-352
	Margin (%)	193	51	57	146	60
	DFS1 Result	**Comply**	**Not comply**	**Not comply**	**Comply**	**Not comply**
Fire Located in Storage Area						
Storage Area	FED (CO)	246	272	337	-	346
	FED (thermal)	90	96	165	-	90
	Visibility	74	74	132	-	74
	ASET (s)	346	74	132	-	346
	Detection Time	70	70	133	-	70
	RSET (s)	123	123	186	-	162
	Margin (s)	223	-49	-54	-	186
	Margin (%)	281	60	71	-	214

Location	Output	Sprinkler	No sprinkler G1	No sprinkler G3	Reduced to two exits	Reduced to single exit
	DFS1 Result	**Comply**	**Not comply**	**Not comply**	**-**	**Comply**
Fire Located in Drive Thru						
Drive Thru	FED (CO)	290	224	297	-	290
	FED (thermal)	99	96	176	-	99
	Visibility	83	96	145	-	83
	ASET (s)	290	96	145	-	290
	Detection Time	72	72	136	-	72
	RSET (s)	152	152	216	-	174
	Margin (s)	138	-56	-71	-	116
	Margin (%)	191	63	67	-	167
	DFS1 Result	**Comply**	**Not comply**	**Not comply**	**-**	**Comply**
Fire Located in Mezzanine						
Mezzanine	FED (CO)	896	349	349	-	896
	FED (thermal)	272	217	217	-	272
	Visibility	96	96	96	-	96
	ASET (s)	896	96	96	-	896
	Detection Time	139	139	139	-	139
	RSET (s)	191	191	191	-	220
	Margin (s)	705	-95	-95	-	676
	Margin (%)	469	50	50	-	207
	DFS1 Result	**Comply**	**Not comply**	**Not comply**	**-**	**Comply**


Retal Area
1000
800
600
400
200
0
-200
-400
Time (s)
Sprinkler
No sprinkler G1
No sprinkler G3
Reduced to two exits
Reduced to single exit
ASET
RSET
Margin (s)


Storage Area
Time (s)
400
350
300
250
200
150
100
50
0
-50
-100
Sprinkler
No sprinkler G1
No sprinkler G3
Reduced to single exit
ASET
RSET
Margin (s)

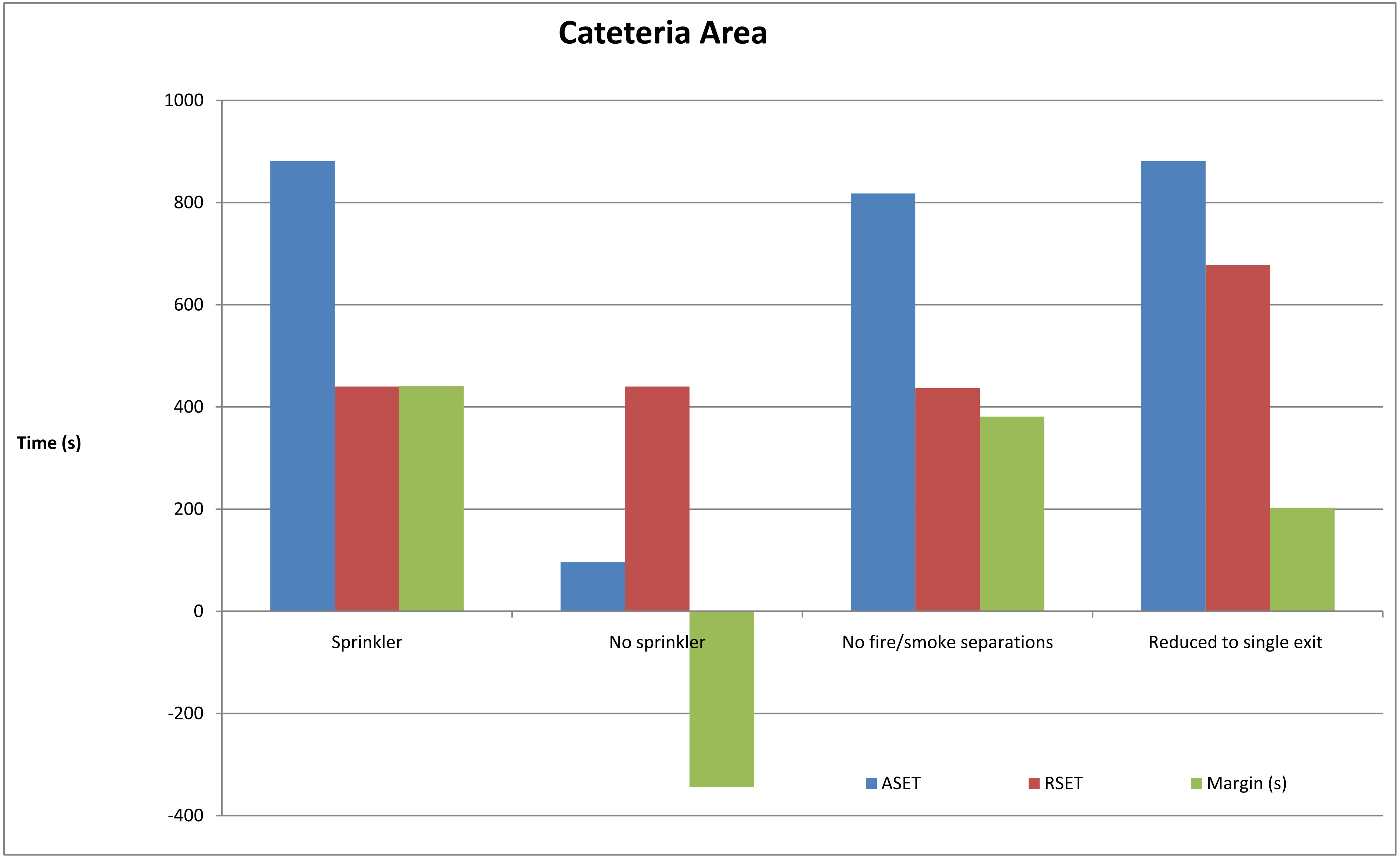

Drive Thru Area
Time (s)
350
300
250
200
150
100
50
0
-50
-100
Sprinkler
No sprinkler G1
No sprinkler G3
Reduced to single exit
ASET
RSET
Margin (s)

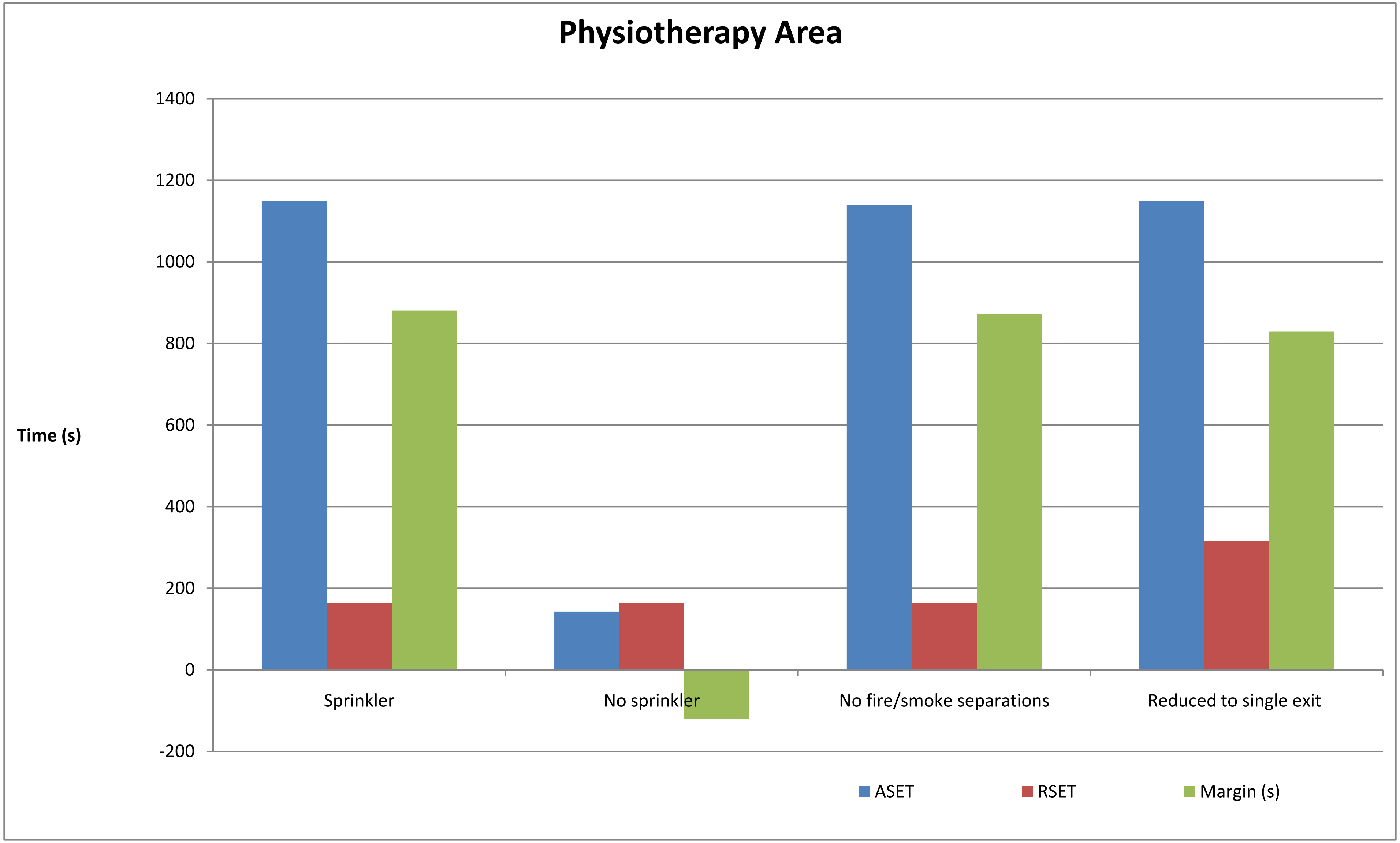

Mezzanine Area
Time (s)
1000
800
600
400
200
0
-200
Sprinkler
No sprinkler G1
No sprinkler G3
Reduced to single exit
ASET
RSET
Margin (s)

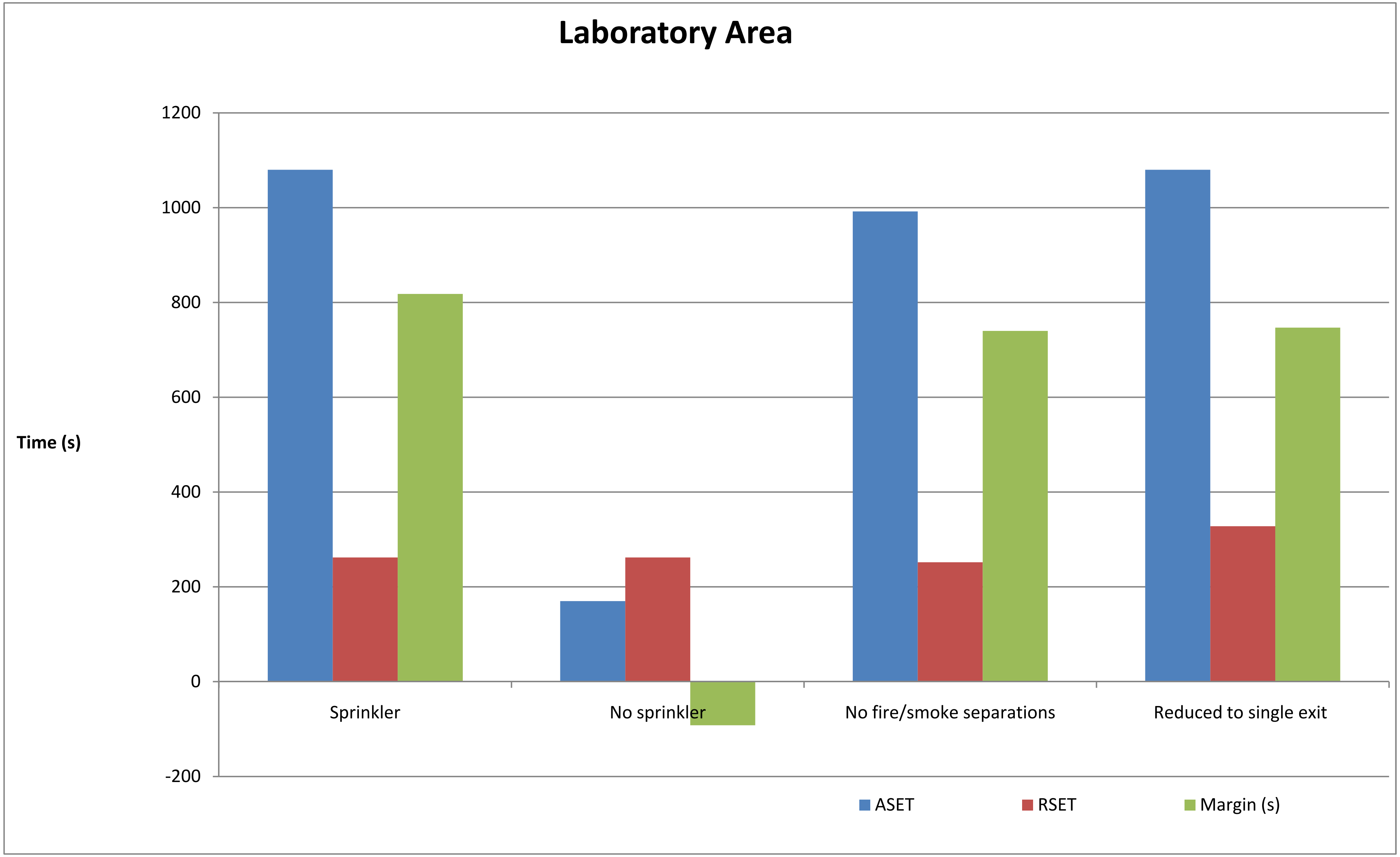
Appendix C2: Case Study Building Two (Hospital)

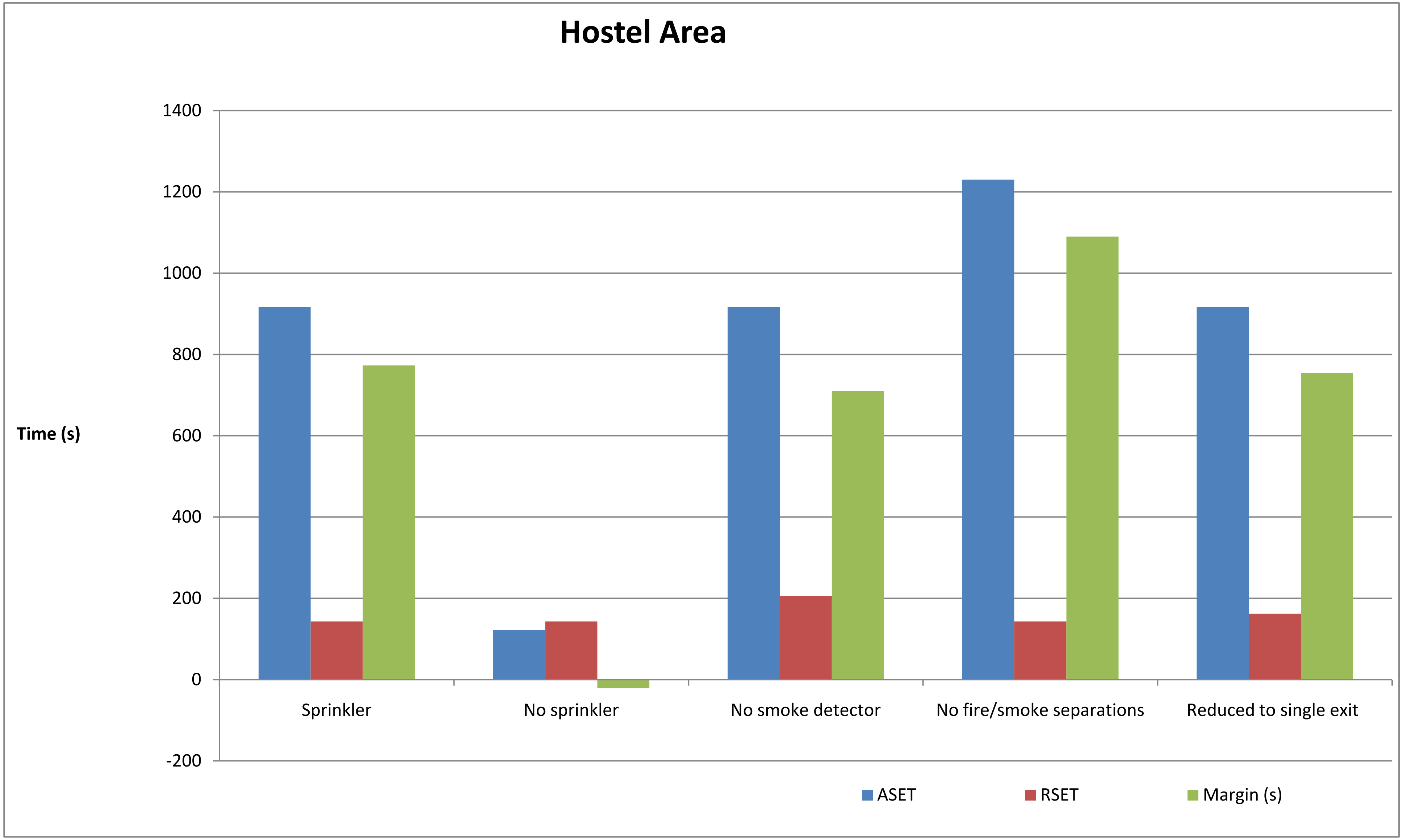
Location	Output	Sprinkler	No sprinkler	No smoke detector	No fire/smoke separations	Reduced to single exit
Fire Located in Cafeteria						
Cafeteria	FED (CO)	881	343	-	818	881
	FED (thermal)	258	215	-	253	258
	Visibility	96	96	-	96	96
	ASET	881	96	-	818	881
	Detection Time	141	141	-	138	141
	RSET	440	440	-	437	678
	Margin (s)	441	-344	-	381	203
	Margin (%)	200	22	-	187	130
	DFS1 Result	**Comply**	**Not comply**	**-**	**Comply**	**Comply**
Fire Located in Physiotherapy						
Physiotherapy	FED (CO)	1150	437	-	1140	1150
	FED (thermal)	454	277	-	455	454
	Visibility	143	143	-	143	143
	ASET	1150	143	-	1140	1150
	Detection Time	153	153	-	153	153
	RSET	164	164	-	164	316
	Margin (s)	881	-121	-	872	829
	Margin (%)	698	87	-	693	362
	DFS1 Result	**Comply**	**Not comply**	**-**	**Comply**	**Comply**

Location	Output	Sprinkler	No sprinkler	No smoke detector	No fire/smoke separations	Reduced to single exit
Fire Located in Laboratory						
Laboratory	FED (CO)	1080	512	-	992	1080
	FED (thermal)	170	312	-	612	170
	Visibility	632	170	-	170	632
	ASET	1080	170	-	992	1080
	Detection Time	160	160	-	157	160
	RSET	262	262	-	252	328
	Margin (s)	818	-92	-	740	747
	Margin (%)	412	64	-	394	328
	DFS1 Result	**Comply**	**Not comply**	**-**	**Comply**	**Comply**
Fire Located in Hostel						
Hostel	FED (CO)	916	419	916	1230	916
	FED (thermal)	545	251	545	550	545
	Visibility	122	122	122	122	122
	ASET	916	122	916	1230	916
	Detection Time	59	59	122	59	59
	RSET	143	143	206	143	162
	Margin (s)	773	-21	710	1090	754
	Margin (%)	641	85	445	859	565
	DFS1 Result	**Comply**	**Not comply**	**Comply**	**Comply**	**Comply**


Cateteria Area
1000
800
600
400
200
0
-200
-400
Time (s)
Sprinkler
No sprinkler
No fire/smoke separations
Reduced to single exit
ASET
RSET
Margin (s)


Physiotherapy Area
1400
1200
1000
800
600
400
200
0
-200
Time (s)
Sprinkler
No sprinkler
No fire/smoke separations
Reduced to single exit
ASET
RSET
Margin (s)

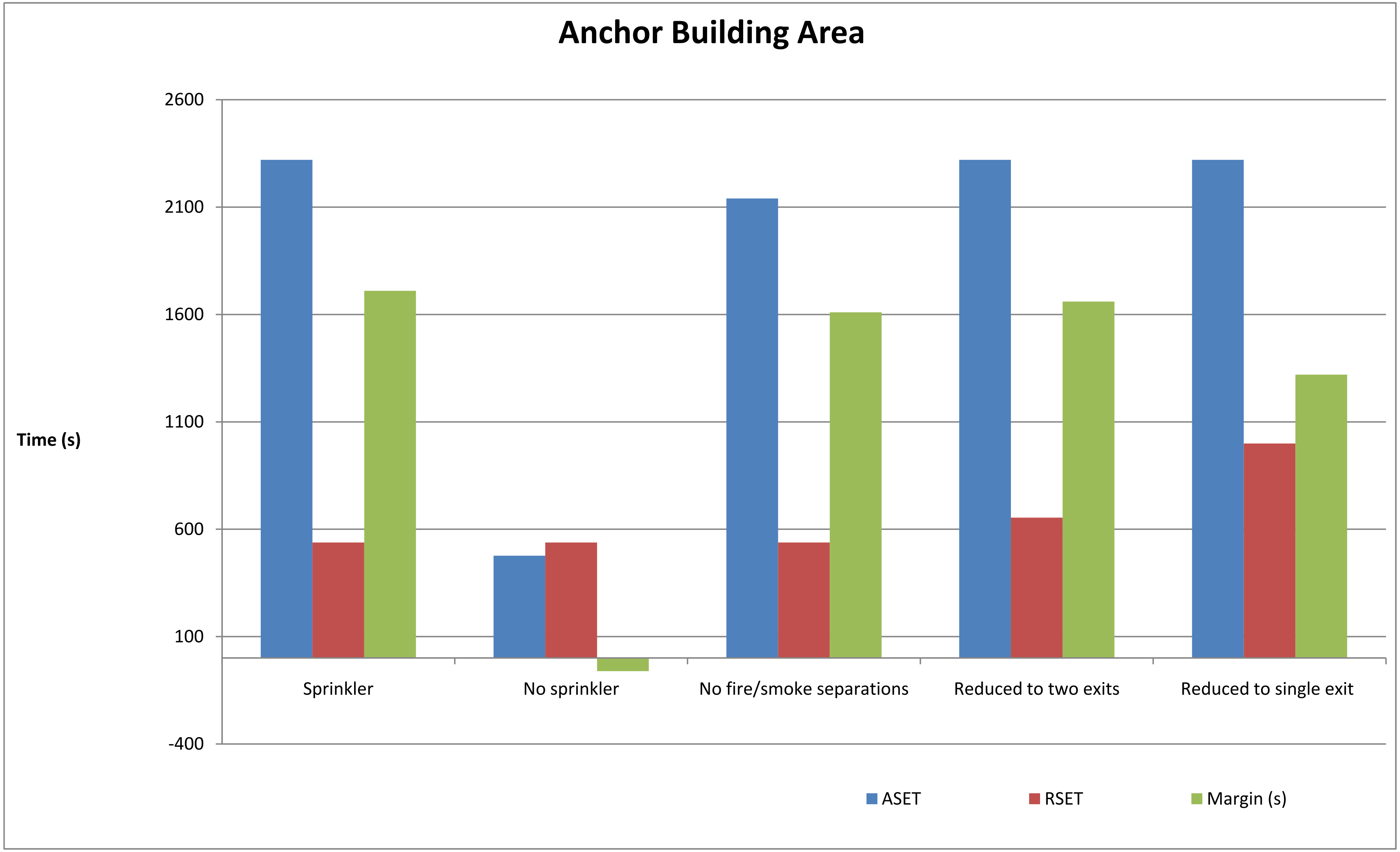

Laboratory Area
Time (s)
1200
1000
800
600
400
200
0
-200
Sprinkler
No sprinkler
No fire/smoke separations
Reduced to single exit
ASET
RSET
Margin (s)

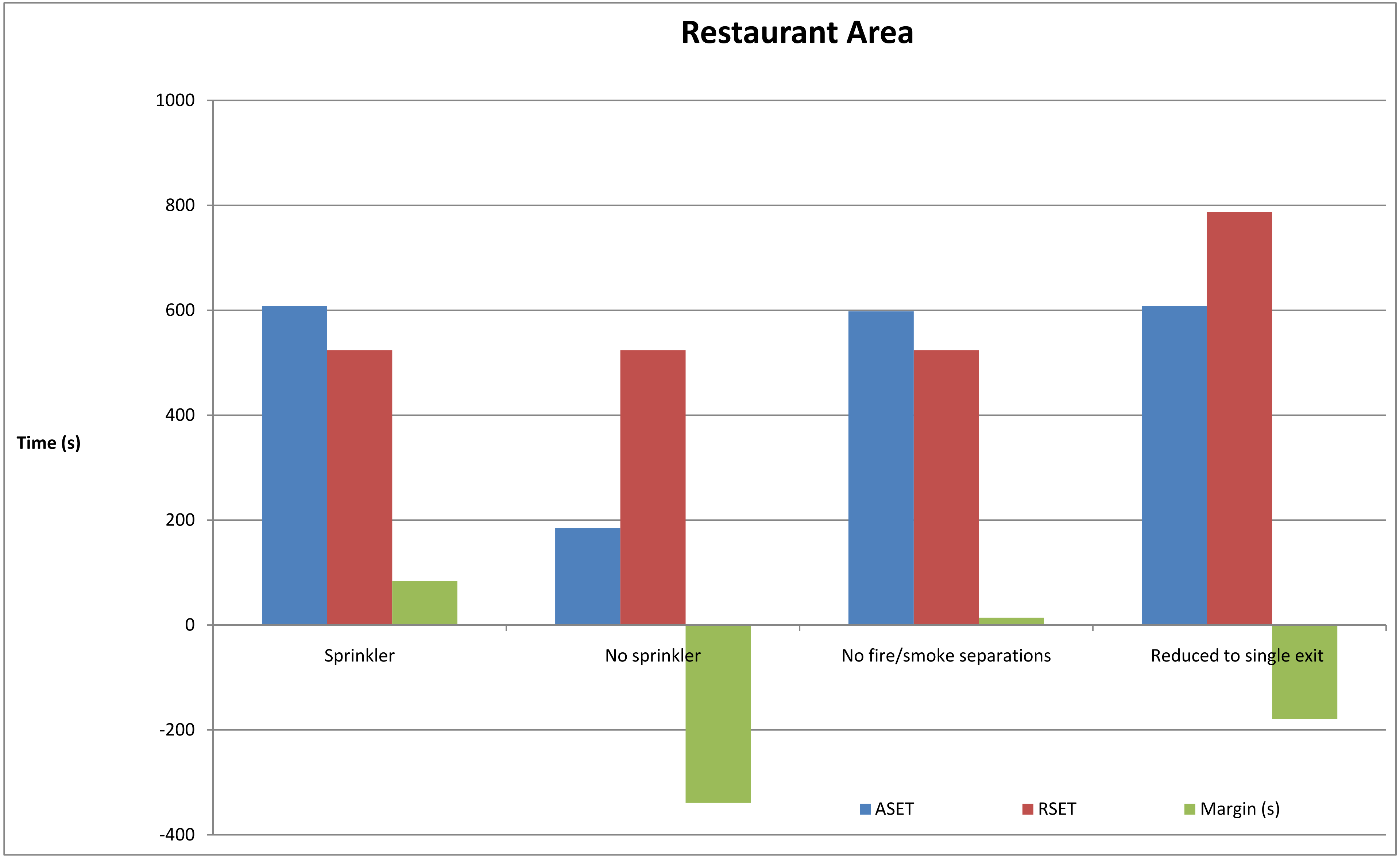

Hostel Area
Time (s)
1400
1200
1000
800
600
400
200
0
-200
Sprinkler
No sprinkler
No smoke detector
No fire/smoke separations
Reduced to single exit
ASET
RSET
Margin (s)

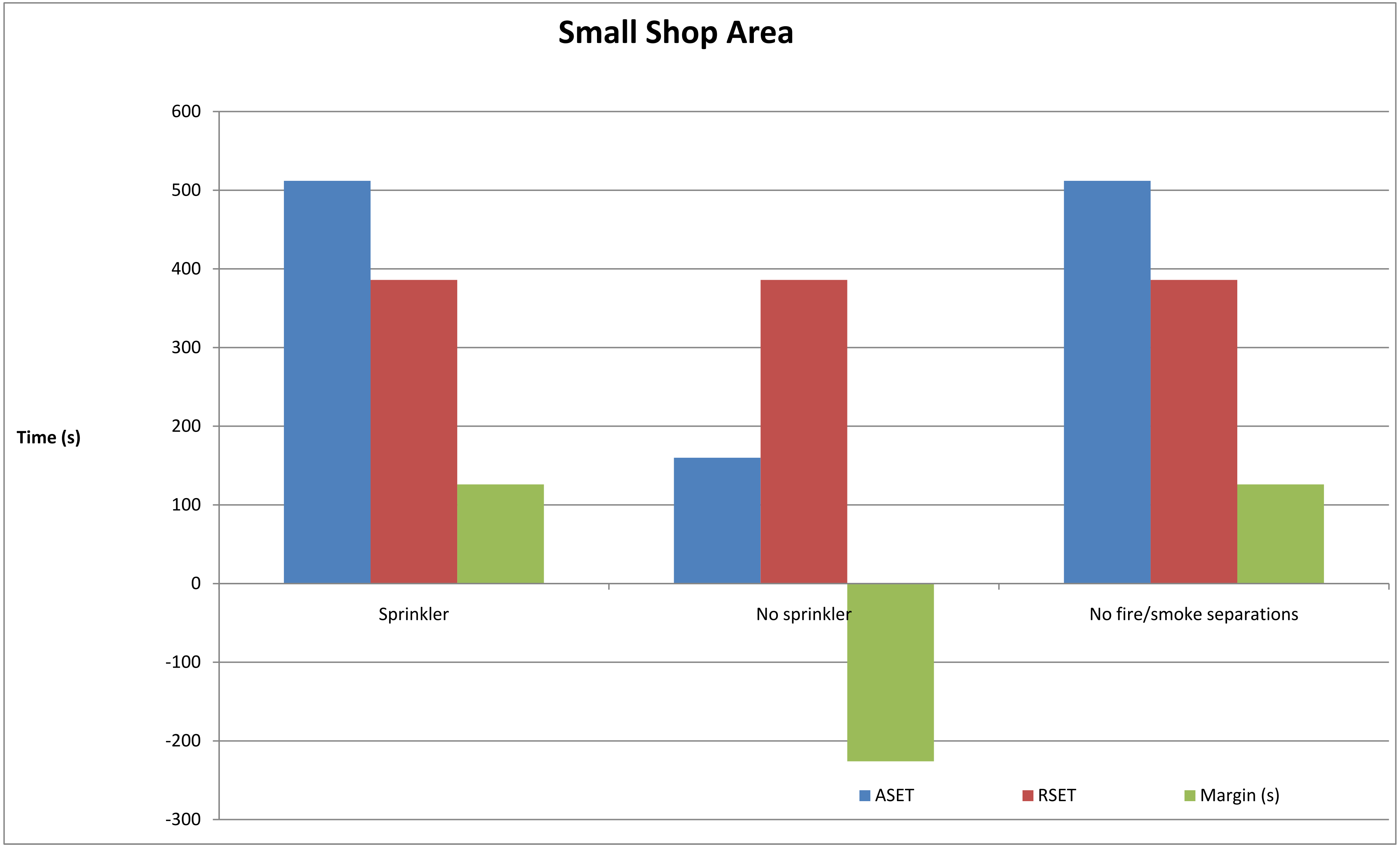
Appendix C3: Case Study Building One (Shopping Mall)

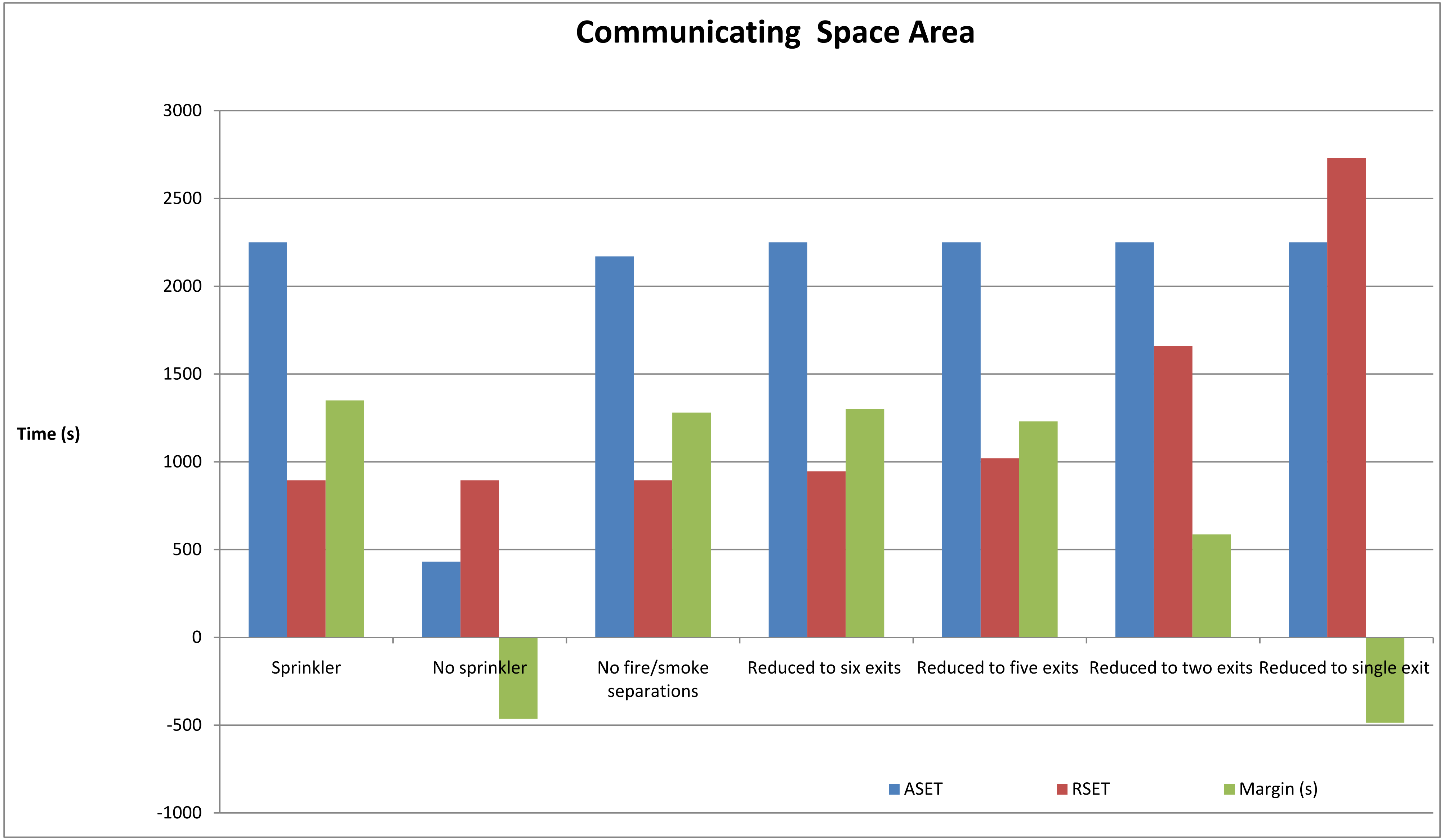
Location	Output	Sprinkler	No sprinkler	No fire/smoke separations	Reduced to six exits	Reduced to five exits	Reduced to two exits	Reduced to single exit
Fire Located in Anchor Building – 3								
Anchor Building – 3	FED (CO)	2320	1020	2140	-	-	2320	2320
	FED	1350	554	1360	-	-	1350	1350
	Visibility	744	477	768	-	-	744	744
	ASET	2320	477	2140	-	-	2320	2320
	Detection	244	244	244	-	-	244	244
	RSET	538	538	538	-	-	654	999
	Margin (s)	1710	-61	1610	-	-	1660	1320
	Margin (%)	431	89	399	-	-	354	232
	DFS1 Result	**Comply**	**Not comply**	**Comply**	**-**	**-**	**Comply**	**Comply**
Fire Located in Restaurant								
Restaurant	FED (CO)	608	451	598	-	-	-	608
	FED	320	275	196	-	-	-	320
	Visibility	192	185	185	-	-	-	192
	ASET	608	185	598	-	-	-	608
	Detection	200	200	200	-	-	-	200
	RSET	524	524	524	-	-	-	787
	Margin (s)	84	-339	14	-	-	-	-179
	Margin (%)	116	35	114	-	-	-	77
	DFS1 Result	**Comply**	**Not comply**	**Comply**	**-**	**-**	**-**	**Not comply**

Location	Output	Sprinkler	No sprinkler	No fire/smoke separations	Reduced to six exits	Reduced to five exits	Reduced to two exits	Reduced to single exit
Fire Located in Small Shop								
Small Shop	FED (CO)	512	309	512	-	-	-	-
	FED	262	252	262	-	-	-	-
	Visibility	160	160	160	-	-	-	-
	ASET	512	160	512	-	-	-	-
	Detection	194	194	194	-	-	-	-
	RSET	386	386	386	-	-	-	-
	Margin (s)	126	-226	126	-	-	-	-
	Margin (%)	133	41	133	-	-	-	-
	DFS1 Result	**Comply**	**Not comply**	**Comply**	**-**	**-**	**-**	**-**
Fire Located in Communicating Space								
Communicating Space	FED (CO)	2250	1699	2170	2250	2250	2250	2250
	FED	431	726	837	431	431	431	431
	Visibility	838	431	431	838	838	838	838
	ASET	2250	431	2170	2250	2250	2250	2250
	Detection	467	467	467	467	467	467	467
	RSET	895	895	895	946	1020	1660	2730
	Margin (s)	1350	-464	1280	1300	1230	587	-486
	Margin (%)	251	48	242	238	221	135	82
	DFS1 Result	**Comply**	**Not comply**	**Comply**	**Comply**	**Comply**	**Comply**	**Not comply**


Anchor Building Area
Time (s)
2600
2100
1600
1100
600
100
-400
Sprinkler
No sprinkler
No fire/smoke separations
Reduced to two exits
Reduced to single exit
ASET
RSET
Margin (s)


Restaurant Area
1000
800
600
400
200
0
-200
-400
Time (s)
Sprinkler
No sprinkler
No fire/smoke separations
Reduced to single exit
ASET
RSET
Margin (s)

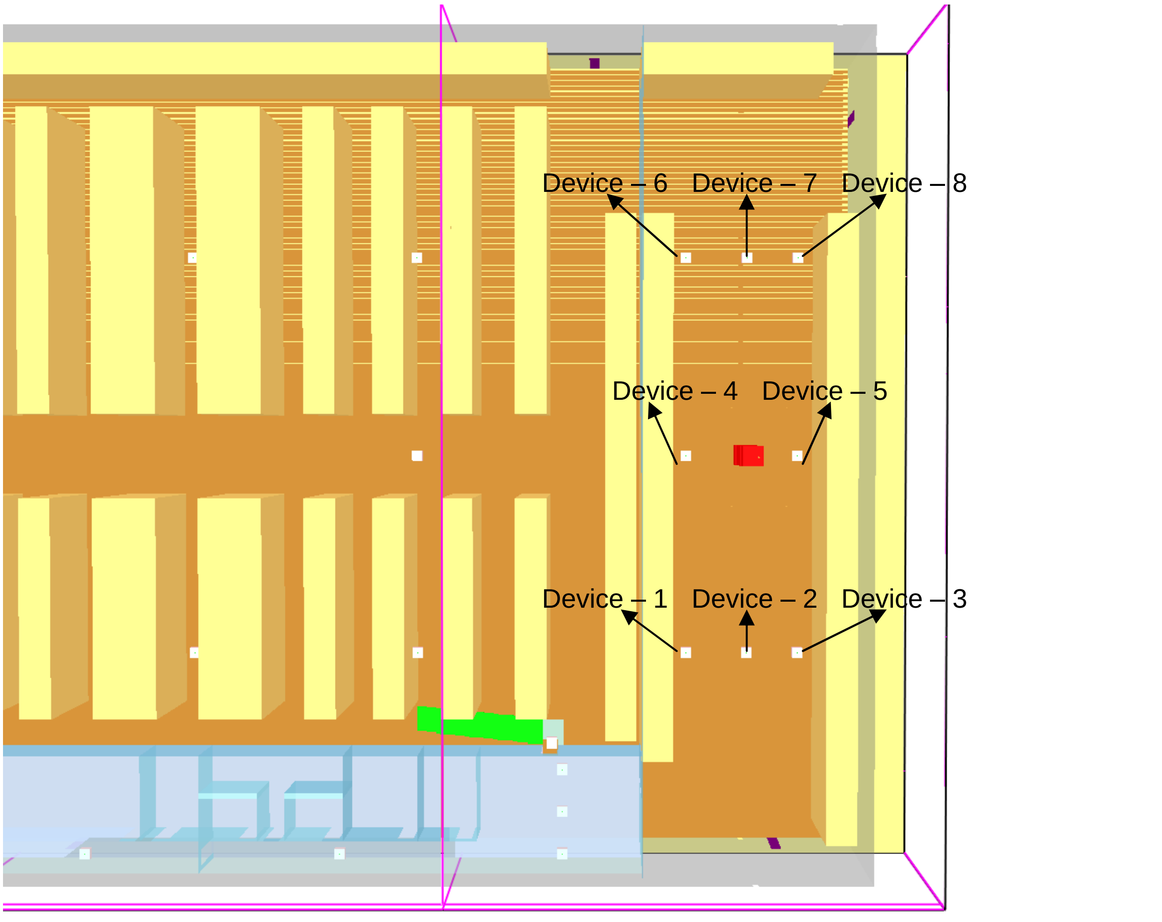

Small Shop Area
600
500
400
300
200
100
0
-100
-200
-300
Time (s)
Sprinkler
No sprinkler
No fire/smoke separations
ASET
RSET
Margin (s)


Communicating Space Area
Time (s)
3000
2500
2000
1500
1000
500
0
-500
-1000
Sprinkler
No sprinkler
No fire/smoke separations
Reduced to six exits
Reduced to five exits
Reduced to two exits
Reduced to single exit
ASET
RSET
Margin (s)

Appendix D: Fire Dynamics Simulator Analysis

Appendix D1: Description of fire modelling in FDS

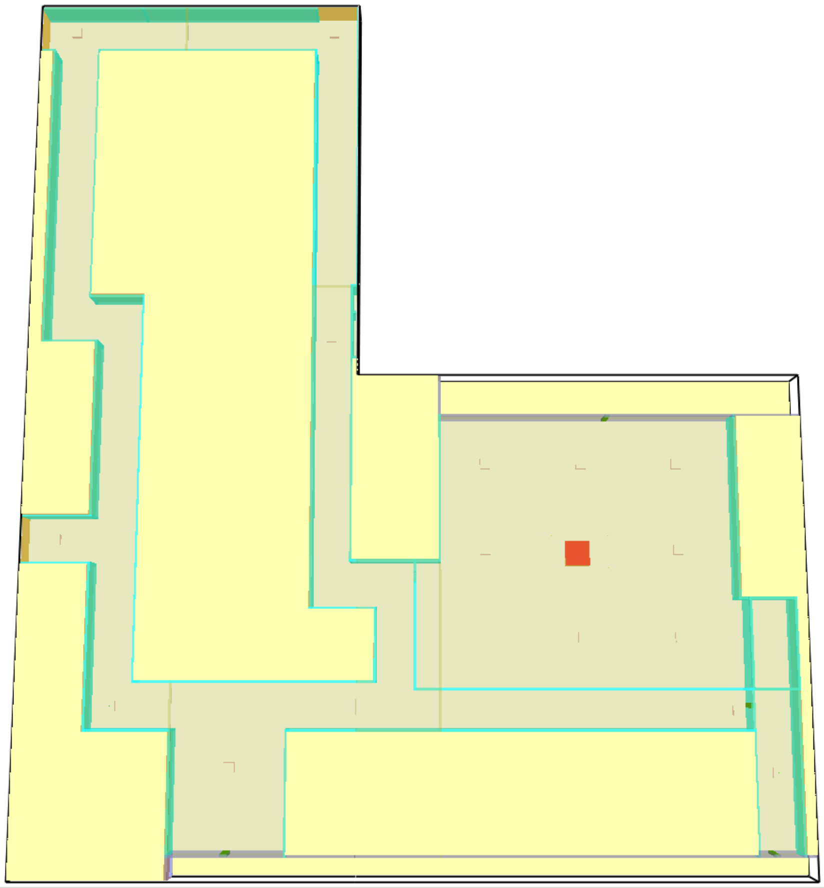
D1.1 Drive thru area in the retail warehouse



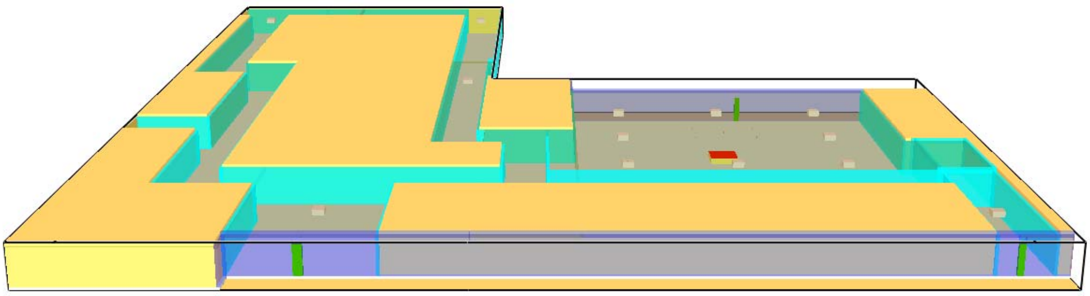
Device locations for drive thru fire

D1.2 Physiotherapy in the hospital

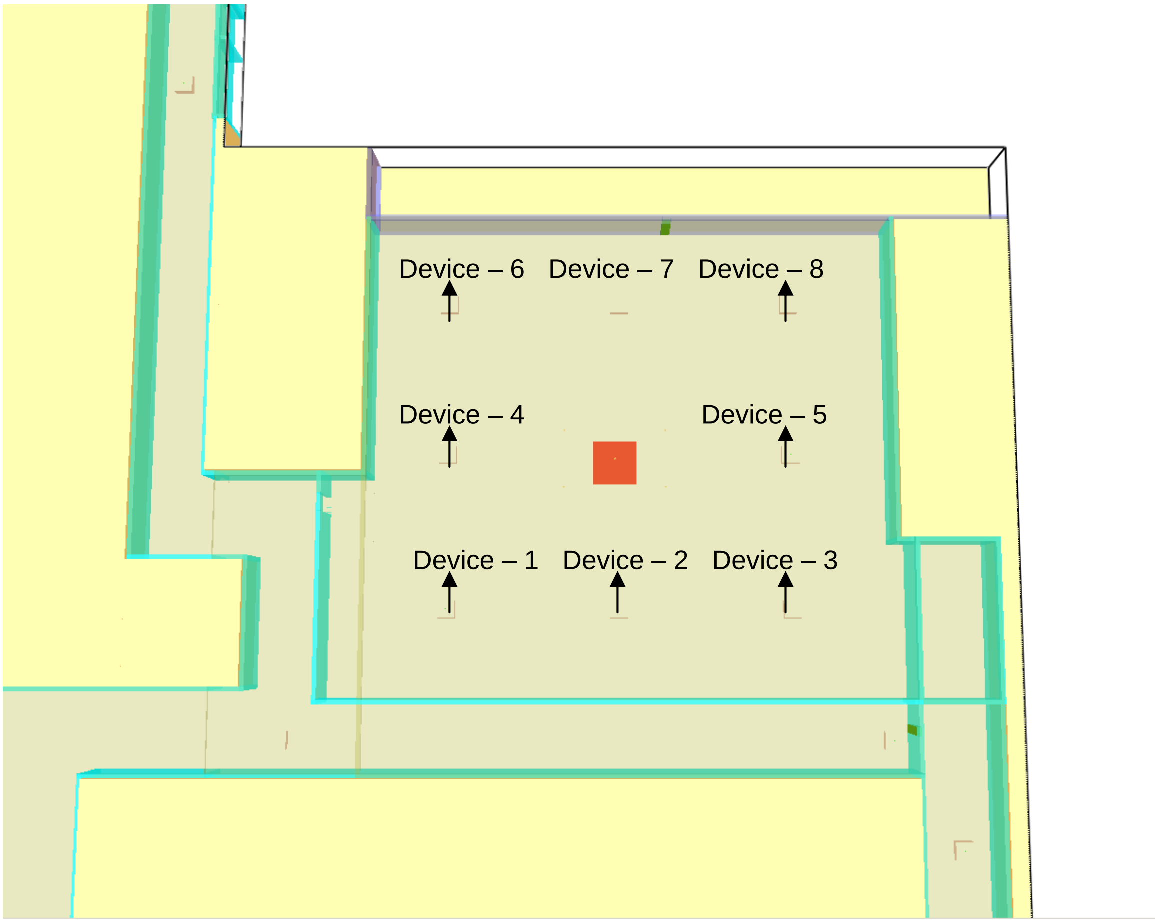
The cell size was 0.20 m by 0.20 m by 0.20 m and the total number of cells in the model was approximately 1.3 million.



Plan view of the physiotherapy and the adjacent corridors on ground floor



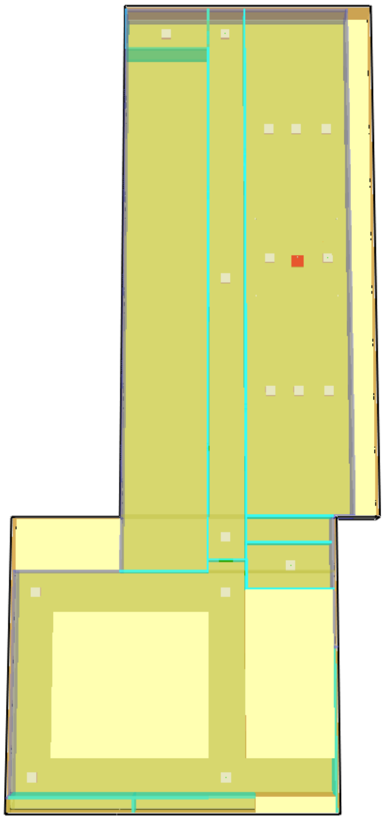
Elevation view of the physiotherapy and the adjacent corridors on ground floor



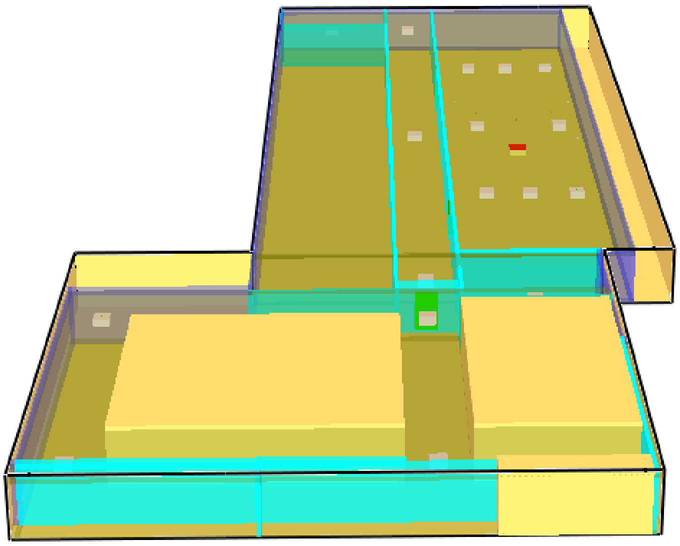
Device locations for physiotherapy fire

D1.3 Hostel in the hospital

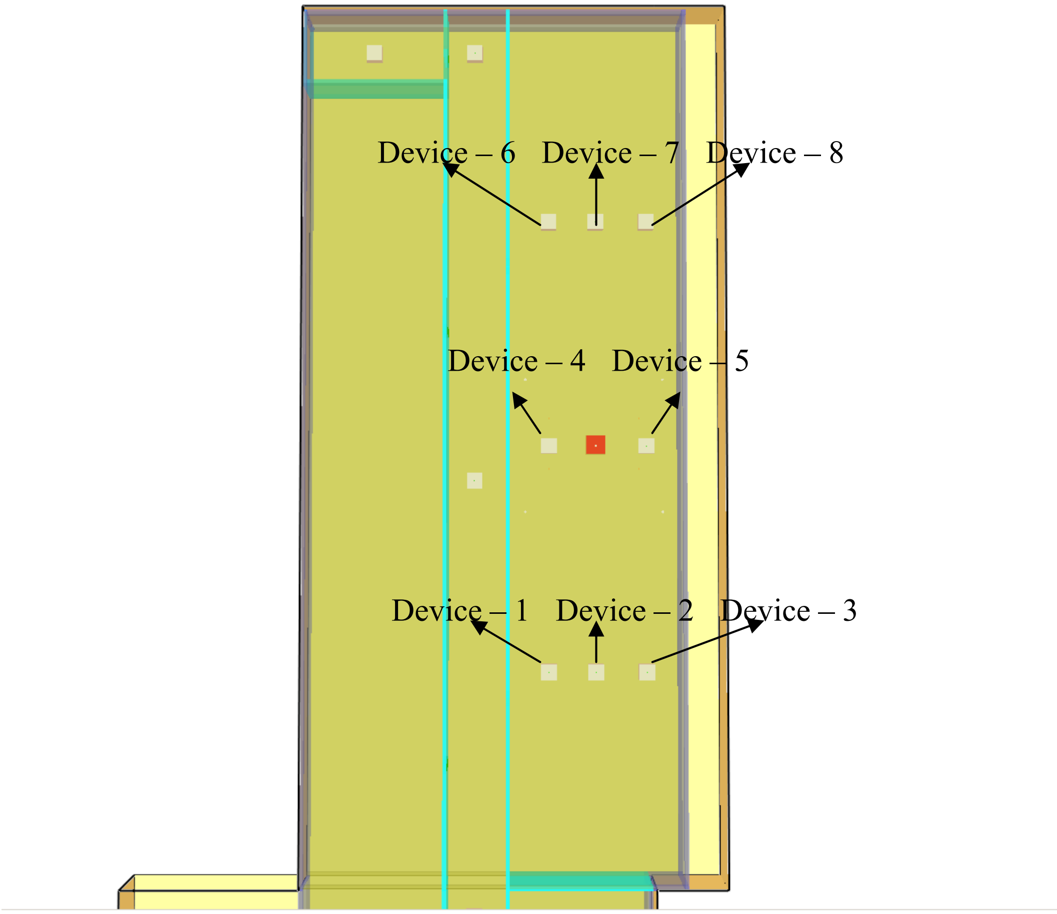
The cell size was 0.20 m by 0.20 m by 0.20 m and the total number of cells in the model was approximately 0.6 million.



Plan view of the hostel and the adjacent corridors on floor 3



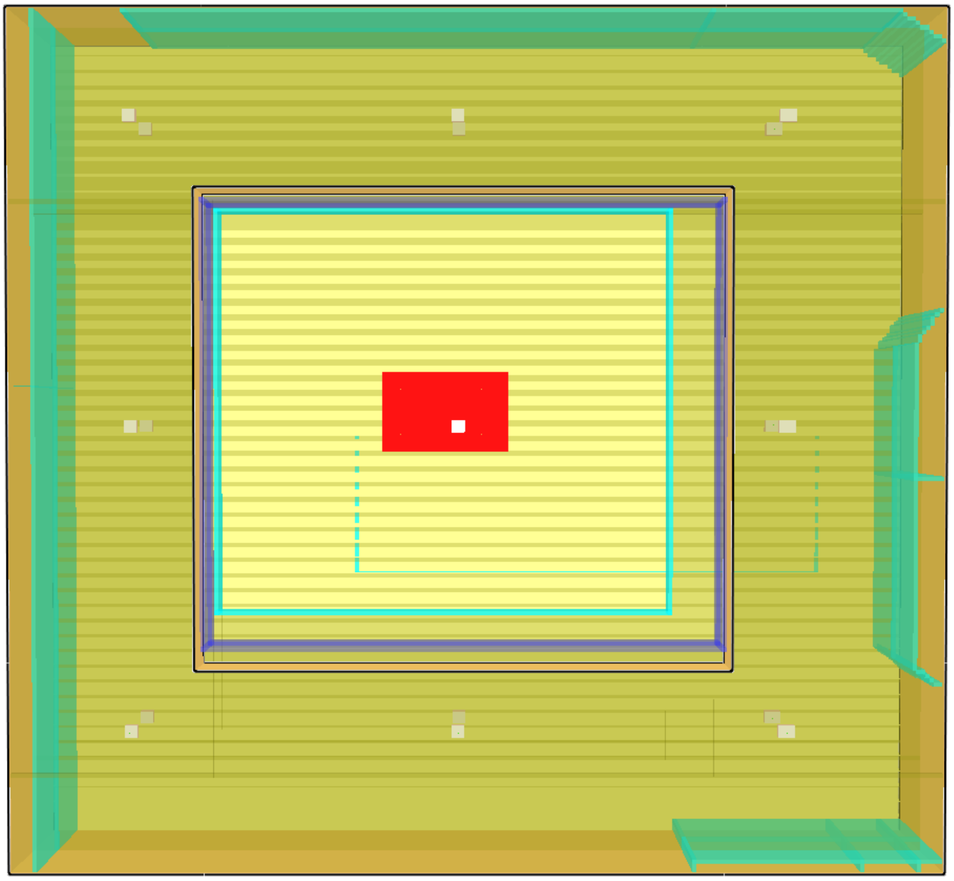
Elevation view of the hostel and the adjacent corridors on floor 3



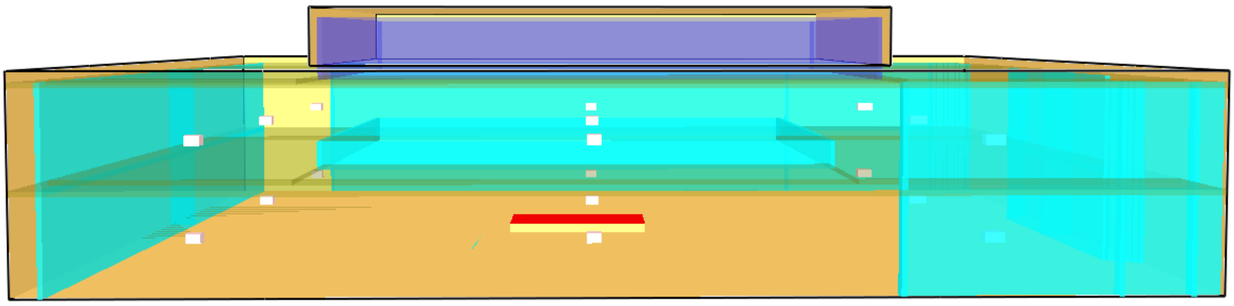
Devices location for hostel fire

D1.4 Communicating space in the shopping mall

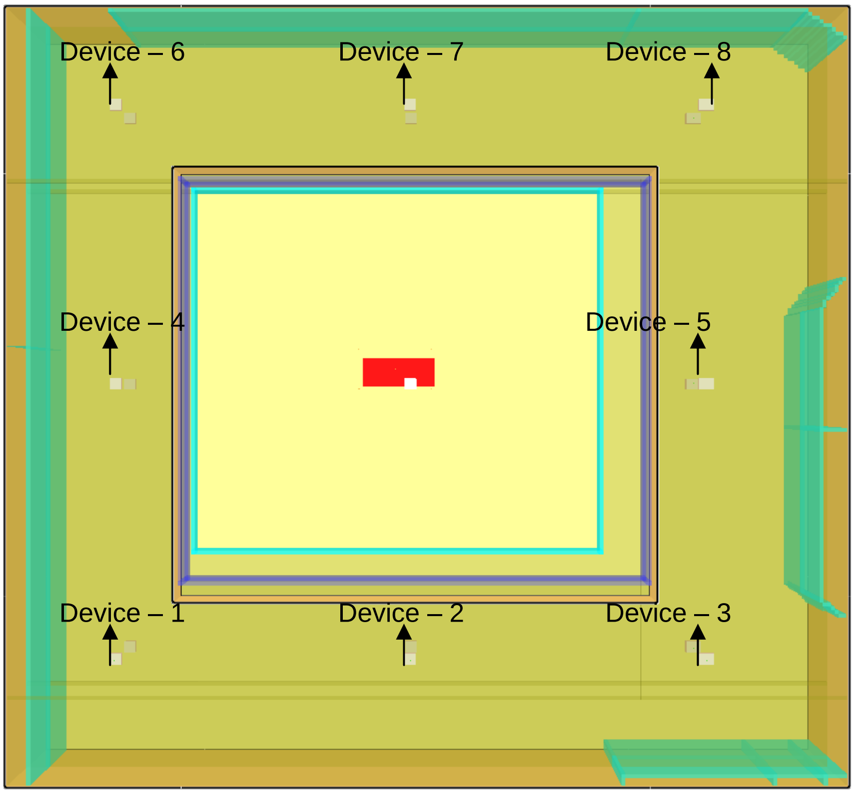
The cell size was 0.25 m by 0.25 m by 0.25 m and the total number of cells in the model was approximately 1.9 million.



Plan view of the communicating space connecting between floor 2 and floor 3 of the shopping mall



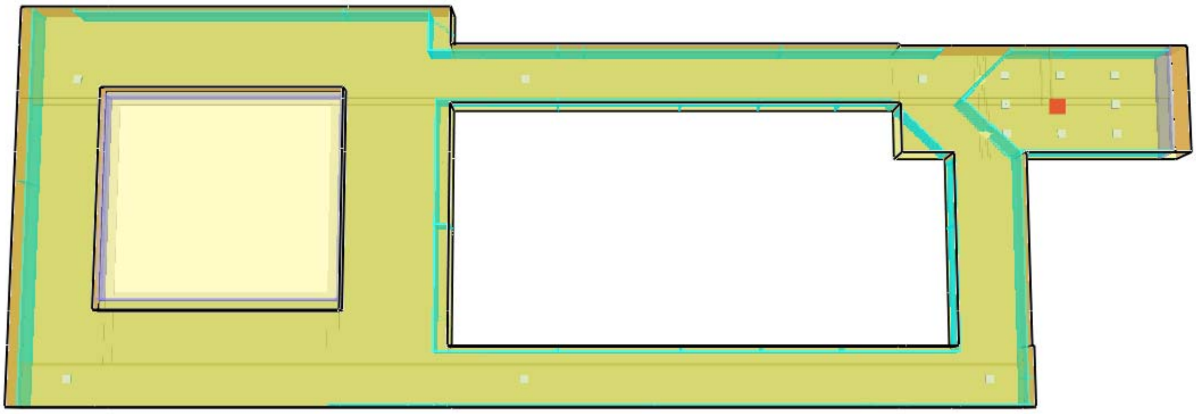
Elevation view of the communicating space connecting between floor 2 and floor 3 of the shopping mall



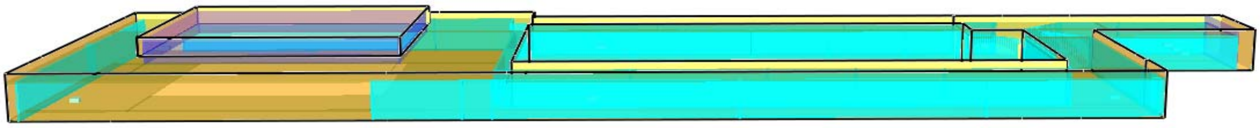
Device locations for communicating space fire

D1.5 Restaurant in the shopping mall

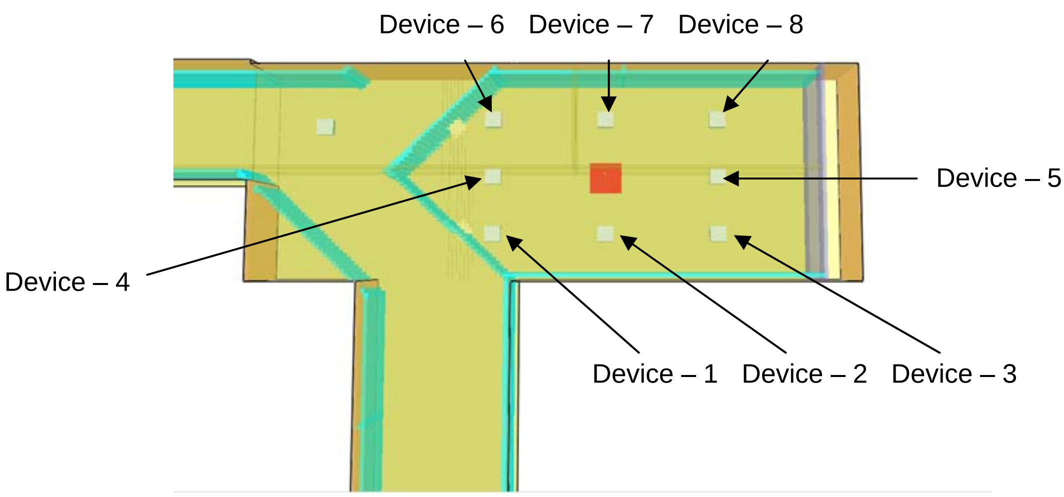
The cell size was 0.25 m by 0.25 m by 0.25 m and the total number of cells in the model was approximately 1.8 million.



Plan view of the restaurant on floor 3



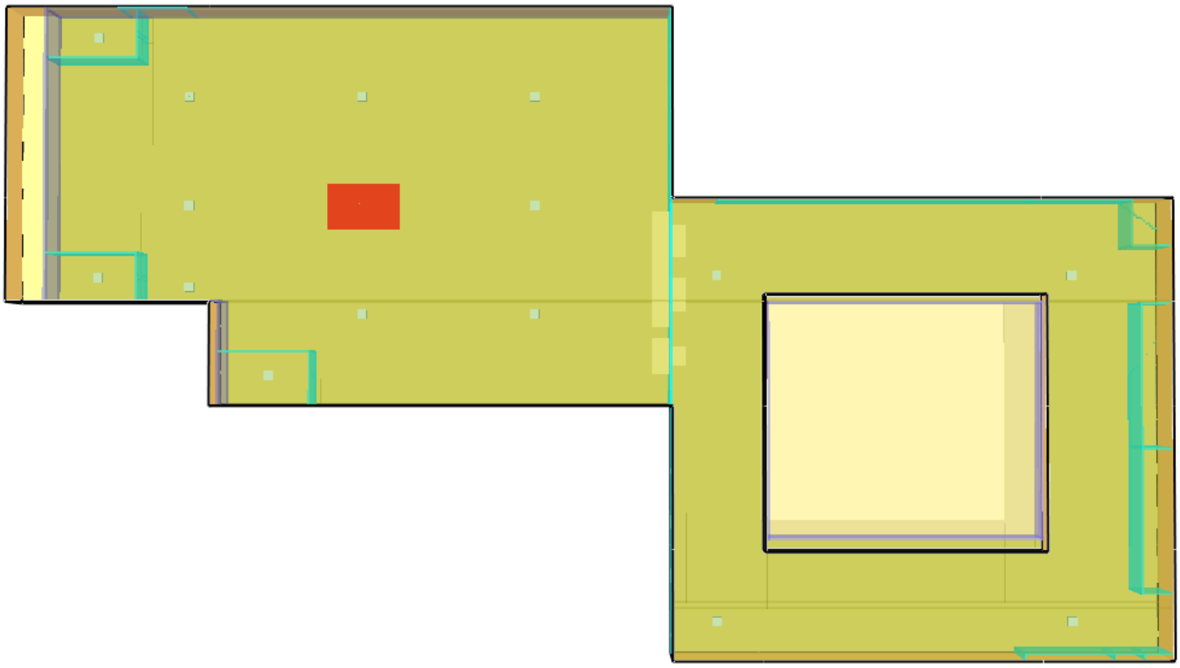
Elevation view of the restaurant on floor 3



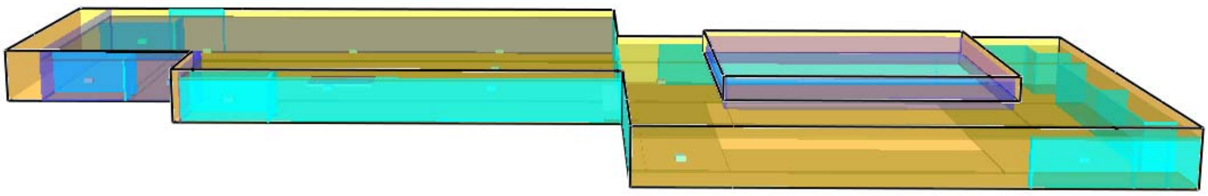
Device locations for restaurant fire

D1.6 Anchor building – 3 in the shopping mall

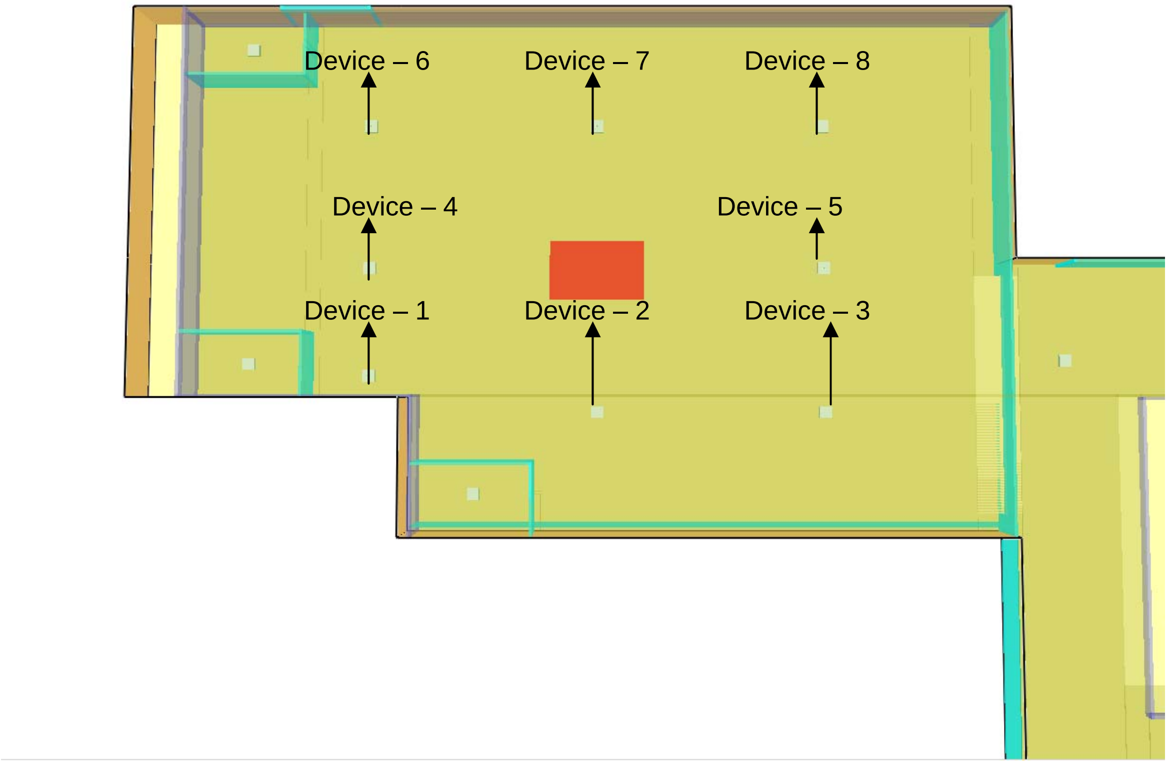
The cell size was 0.25 m by 0.25 m by 0.25 m and the total number of cells in the model was approximately 2.3 million.



Plan view of the anchor building on floor 3



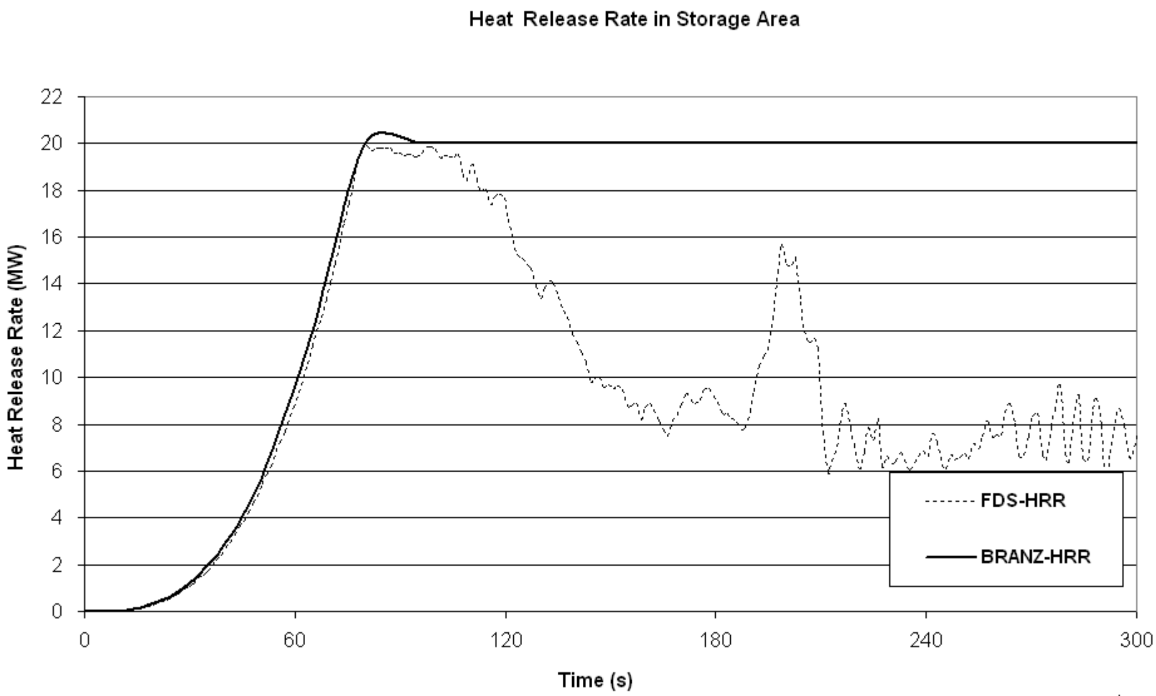
Elevation view of the anchor building on floor 3



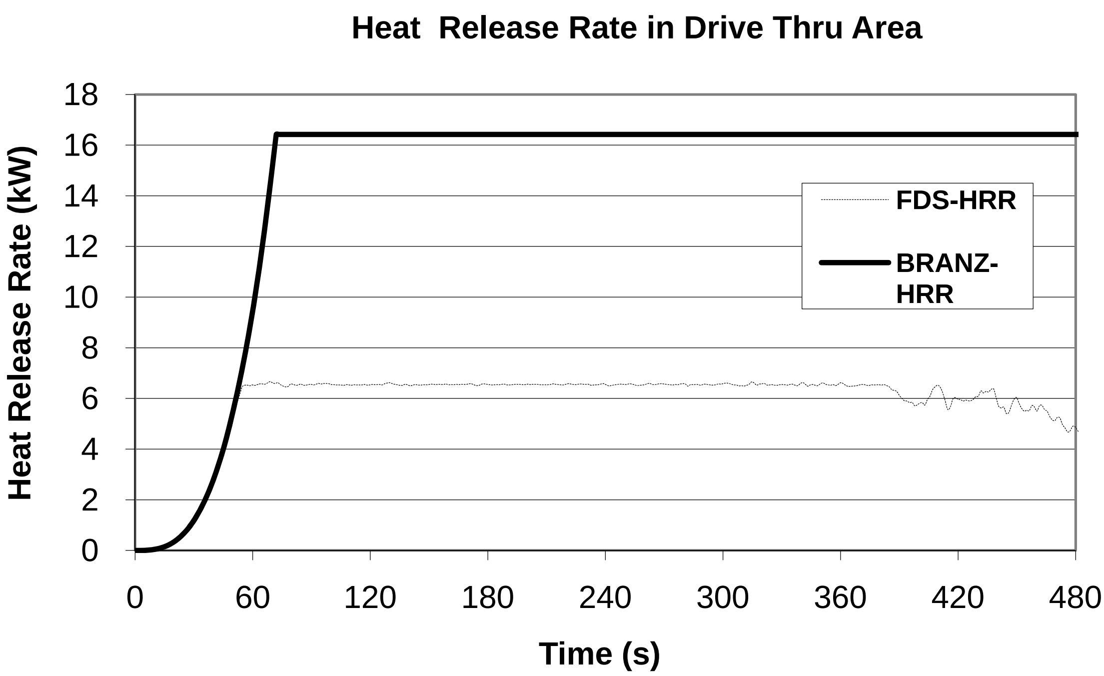
Device locations for anchor building fire

Appendix D2: Design Fire

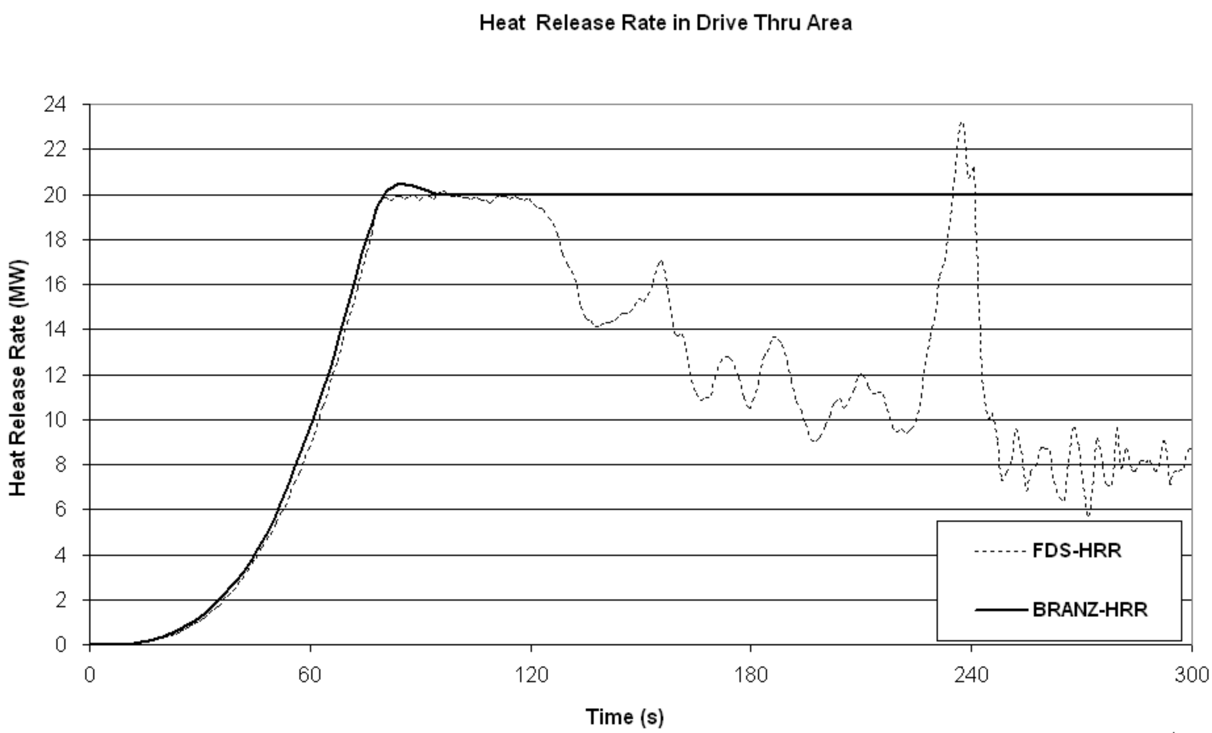
D2.1 Storage fire (not protected with sprinkler system)



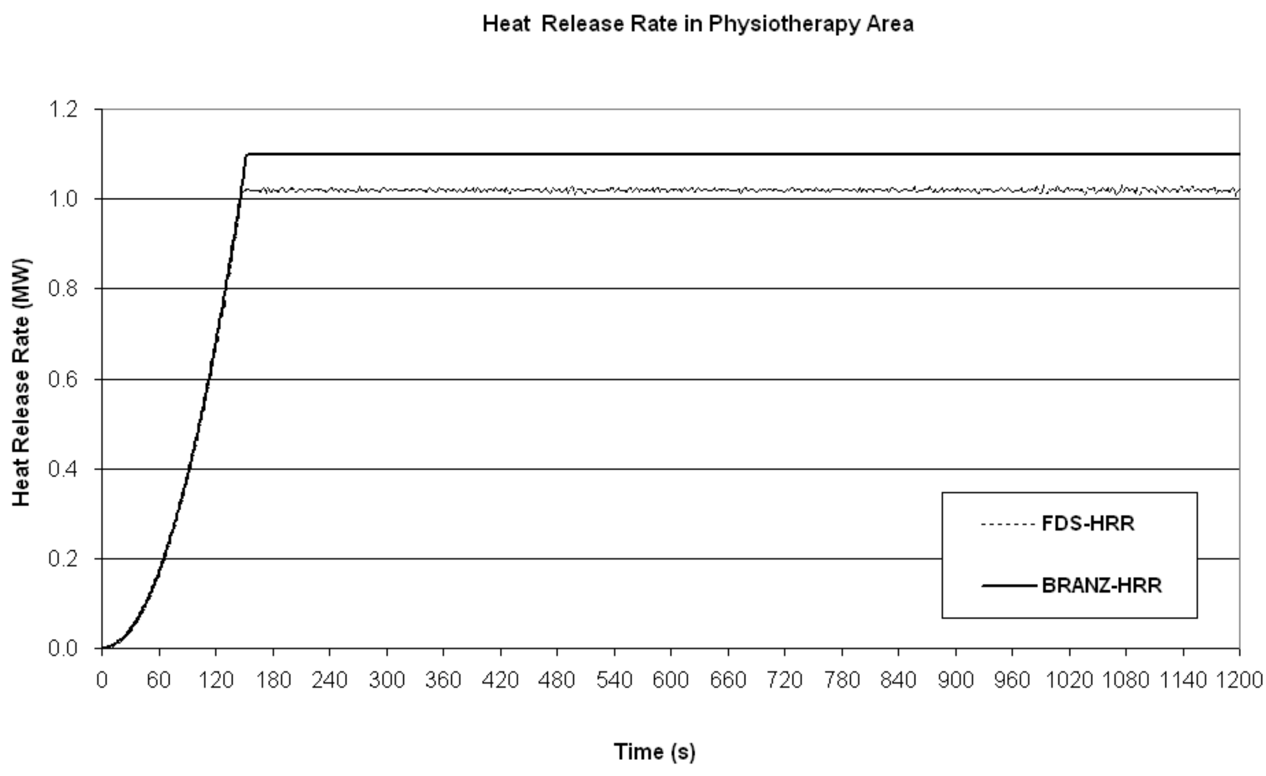
D2.2 Drive thru fire (protected with sprinkler system)



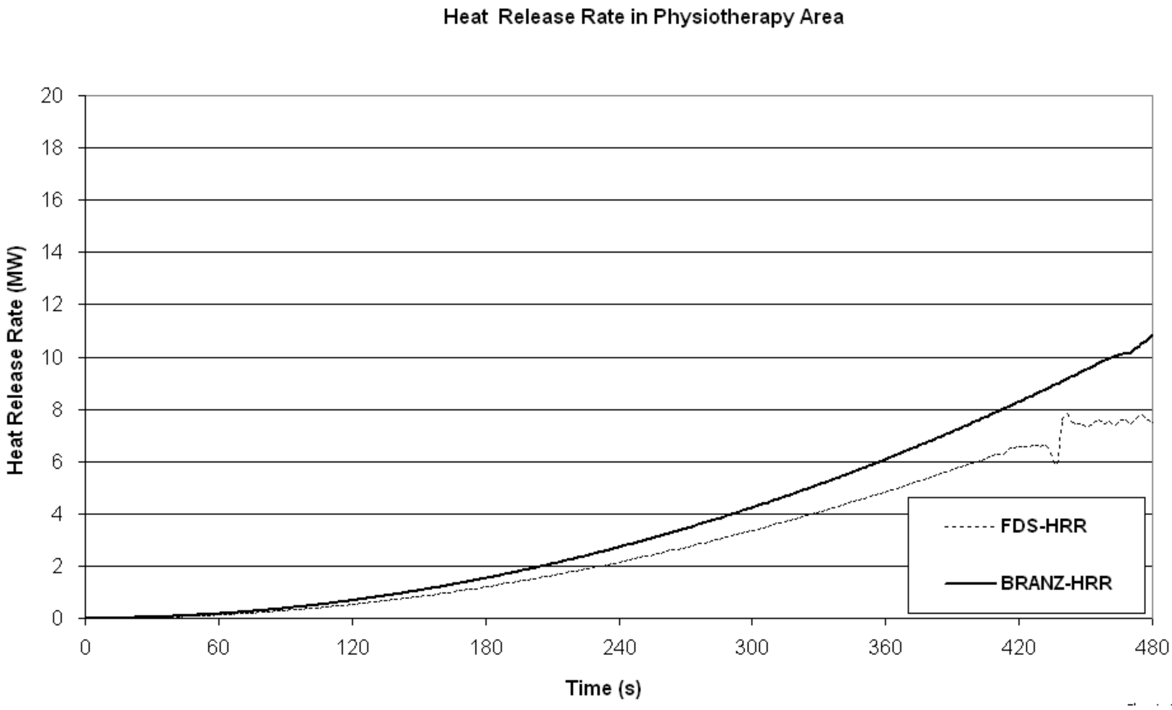
D2.3 Drive thru fire (not protected with sprinkler system)



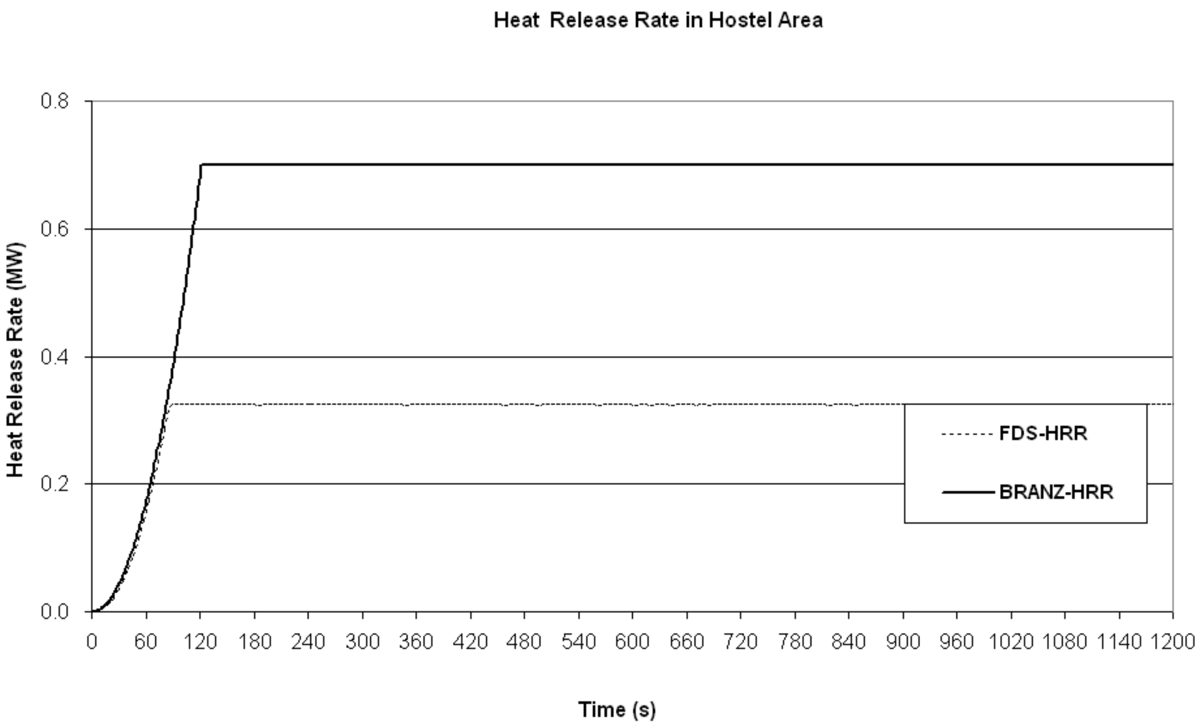
D2.4 Physiotherapy fire (protected with sprinkler system)



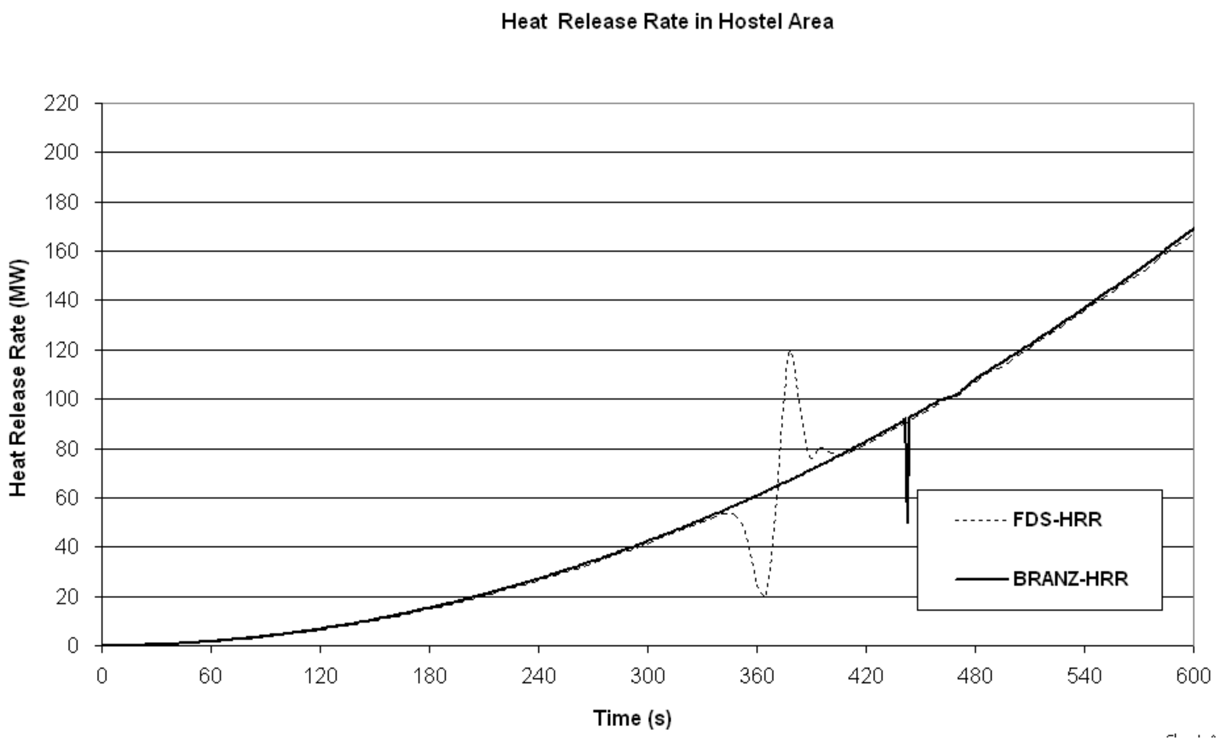
D2.5 Physiotherapy fire (not protected with sprinkler system)



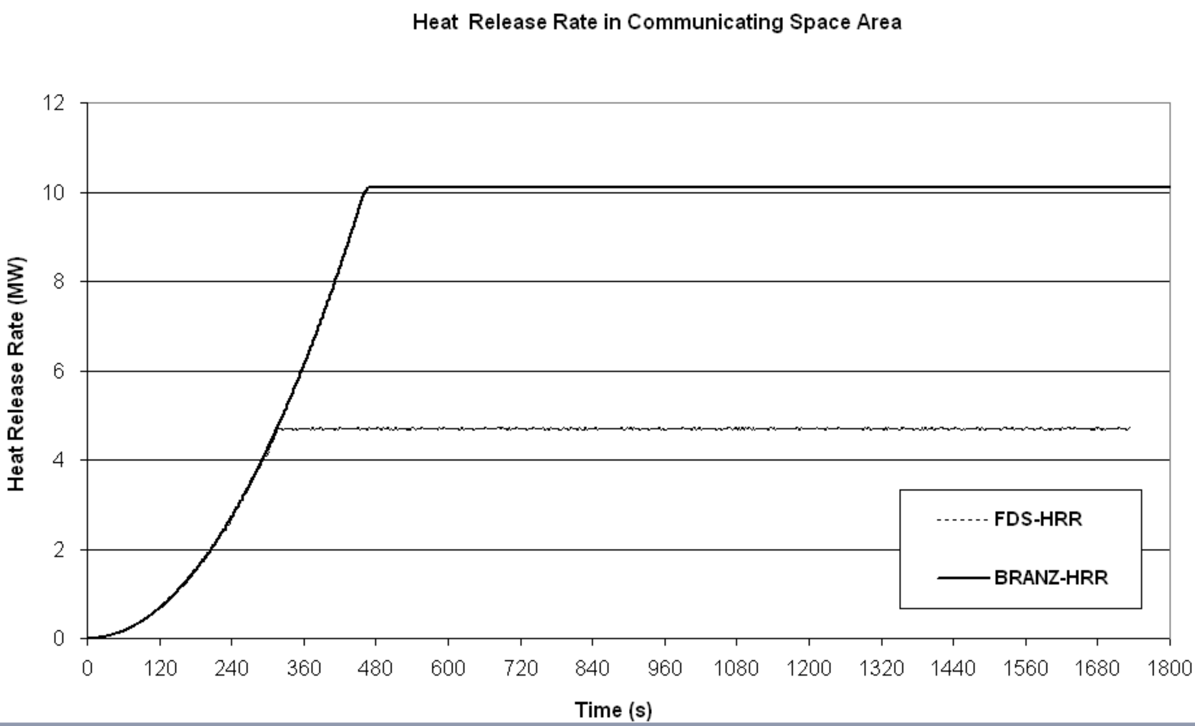
D2.6 Hostel fire (protected with sprinkler system)



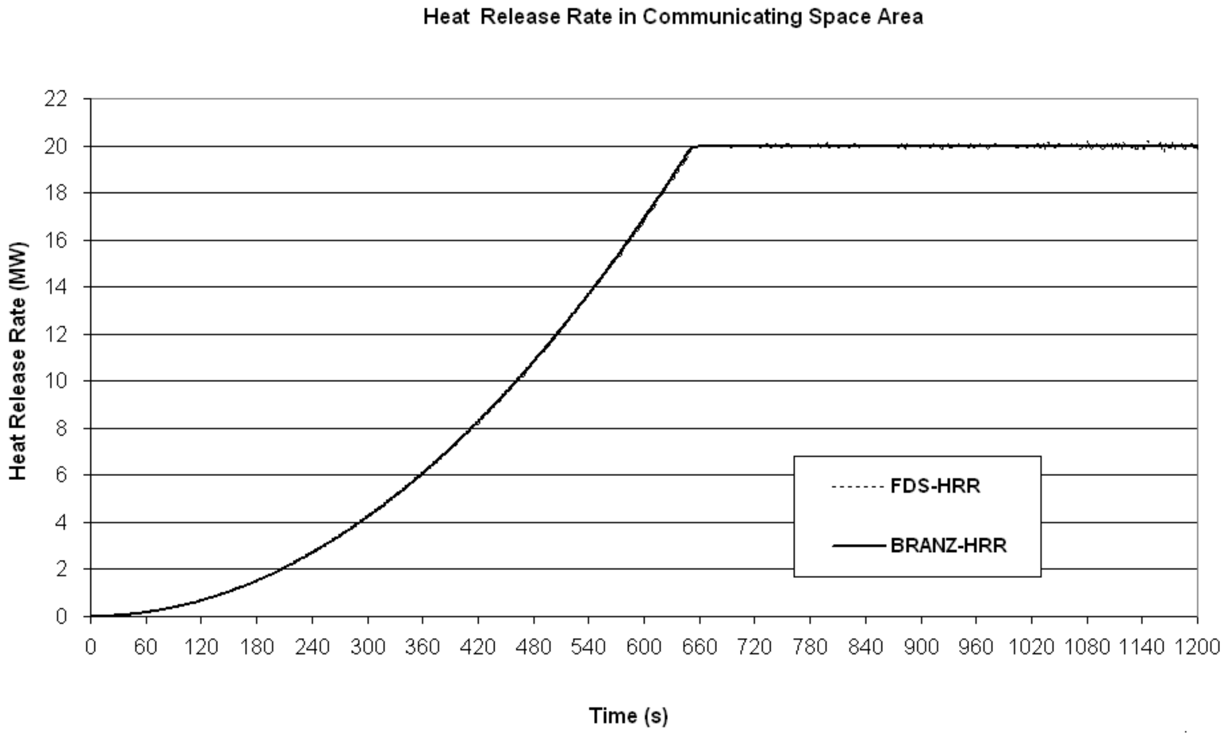
D2.7 Hostel fire (Not protected with sprinkler system)



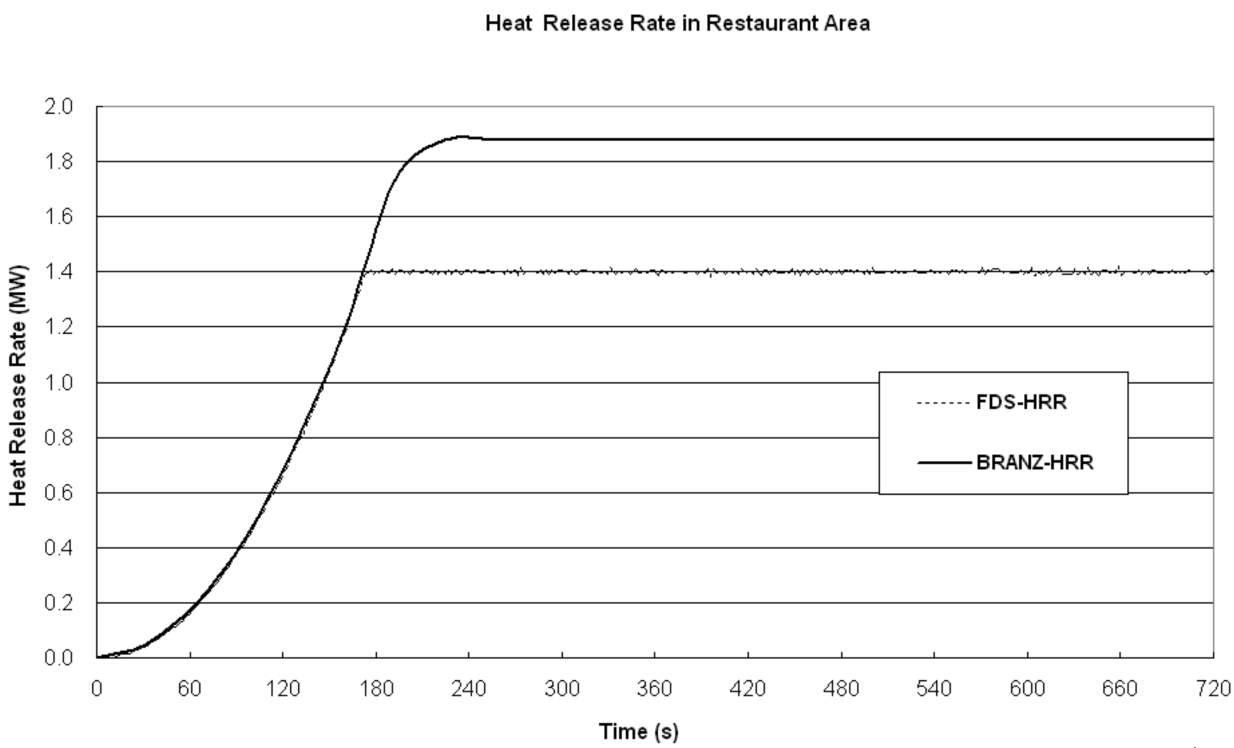
D2.8 Communicating space fire (protected with sprinkler system)



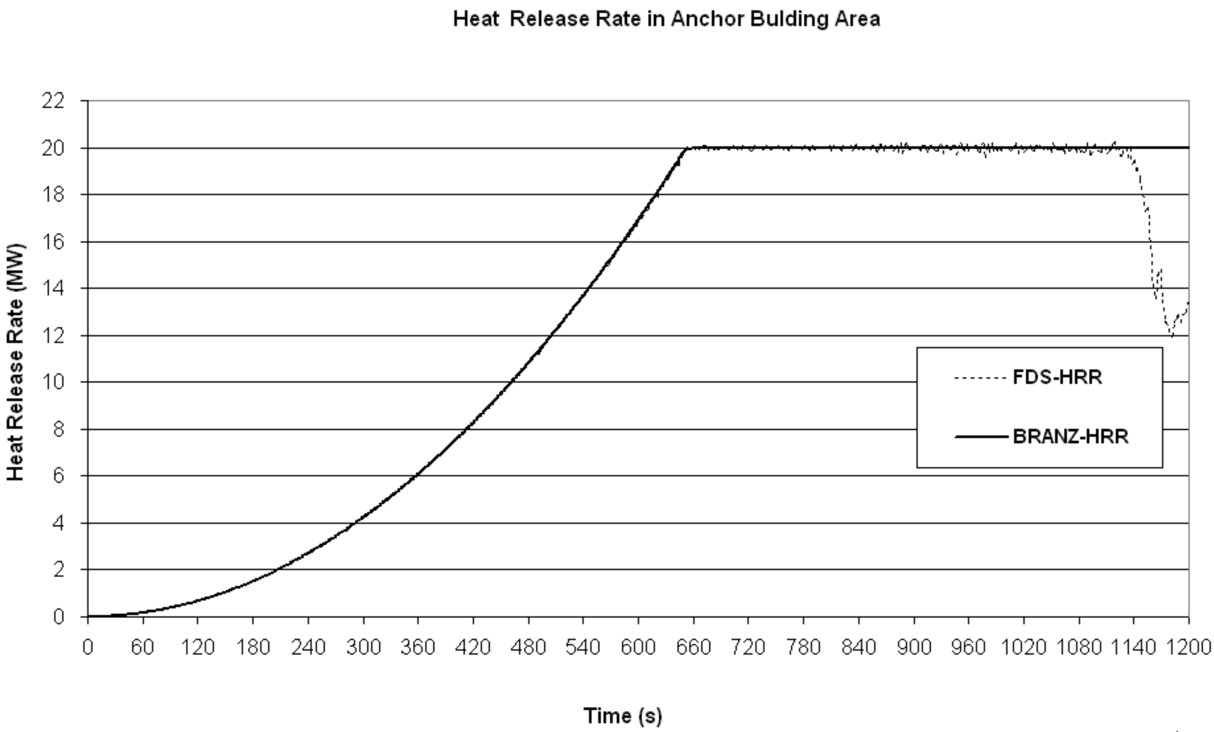
D2.9 Communicating space fire (not protected with sprinkler system)



D2.10 Restaurant fire (protected with sprinkler system)



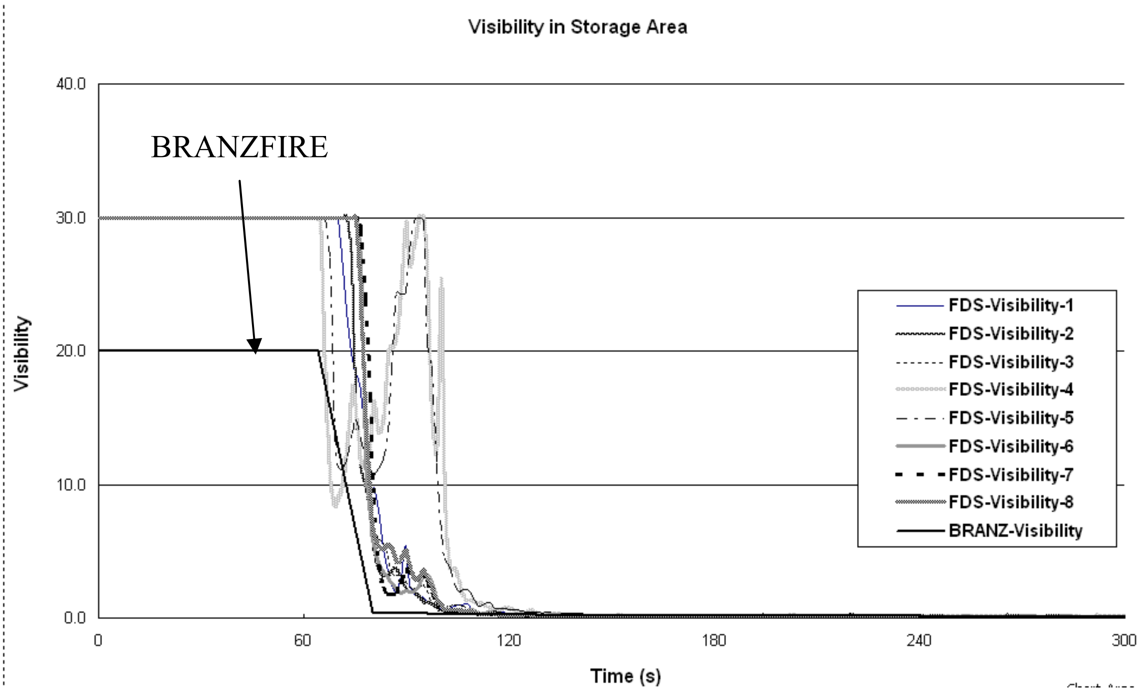
D2.11 Anchor building – 3 fire (not protected with sprinkler system)


Heat Release Rate in Anchor Bulding Area
Heat Release Rate (MW)
Time (s)
FDS-HRR
BRANZ-HRR
0
2
4
6
8
10
12
14
16
18
20
22
0
60
120
180
240
300
360
420
480
540
600
660
720
780
840
900
960
1020
1080
1140
1200

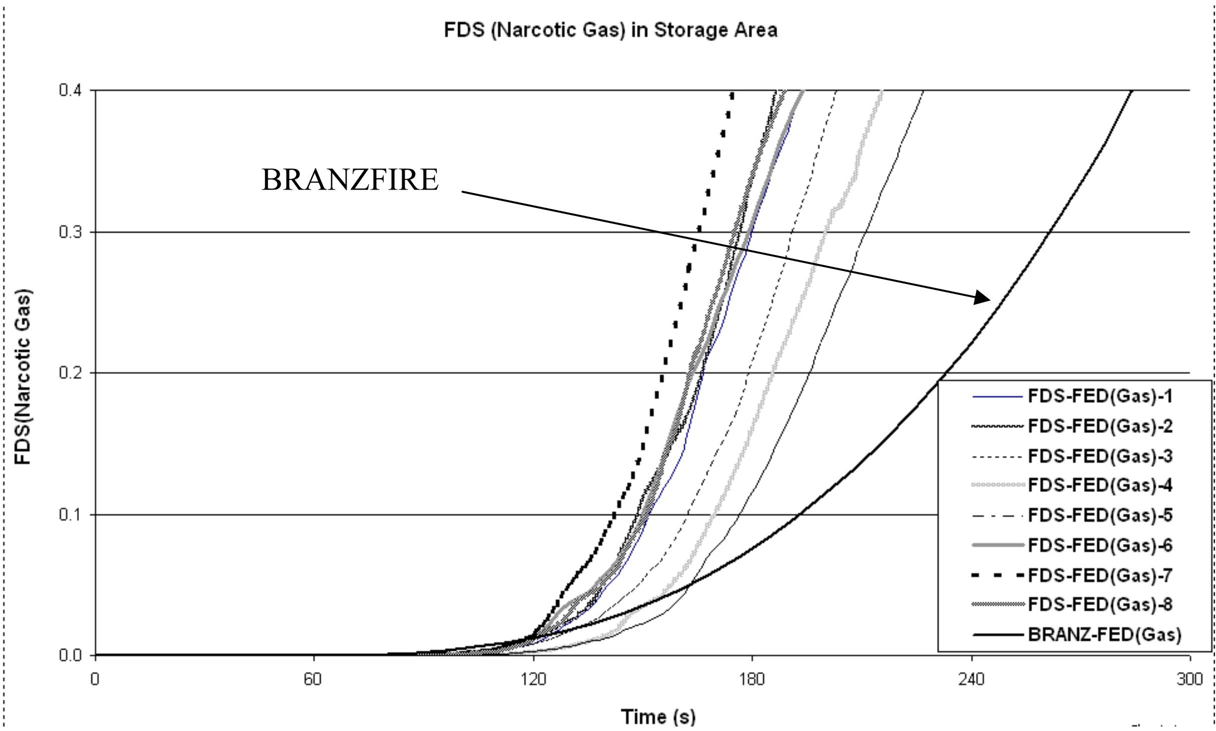
Appendix D3: FDS modelling results

D3.1 Storage fire (not protected with sprinkler system)

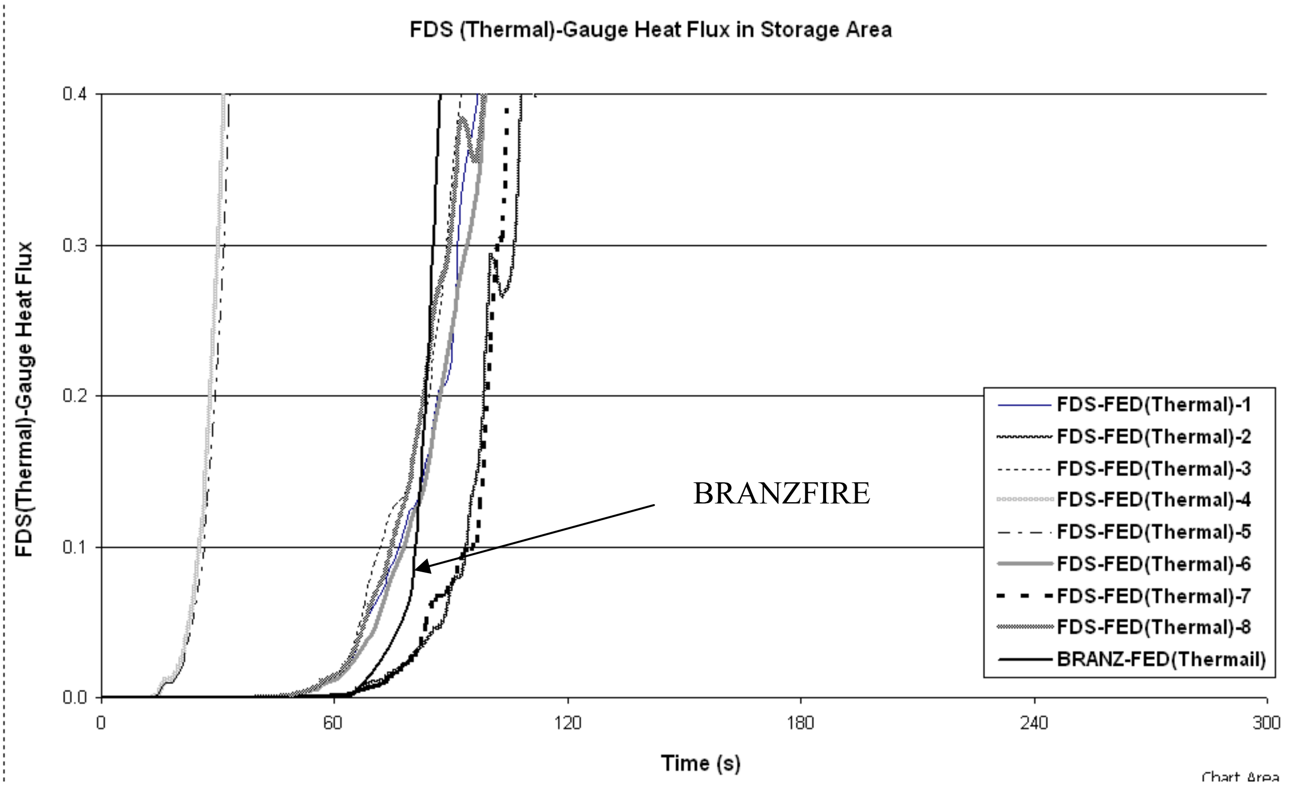
Visibility curves



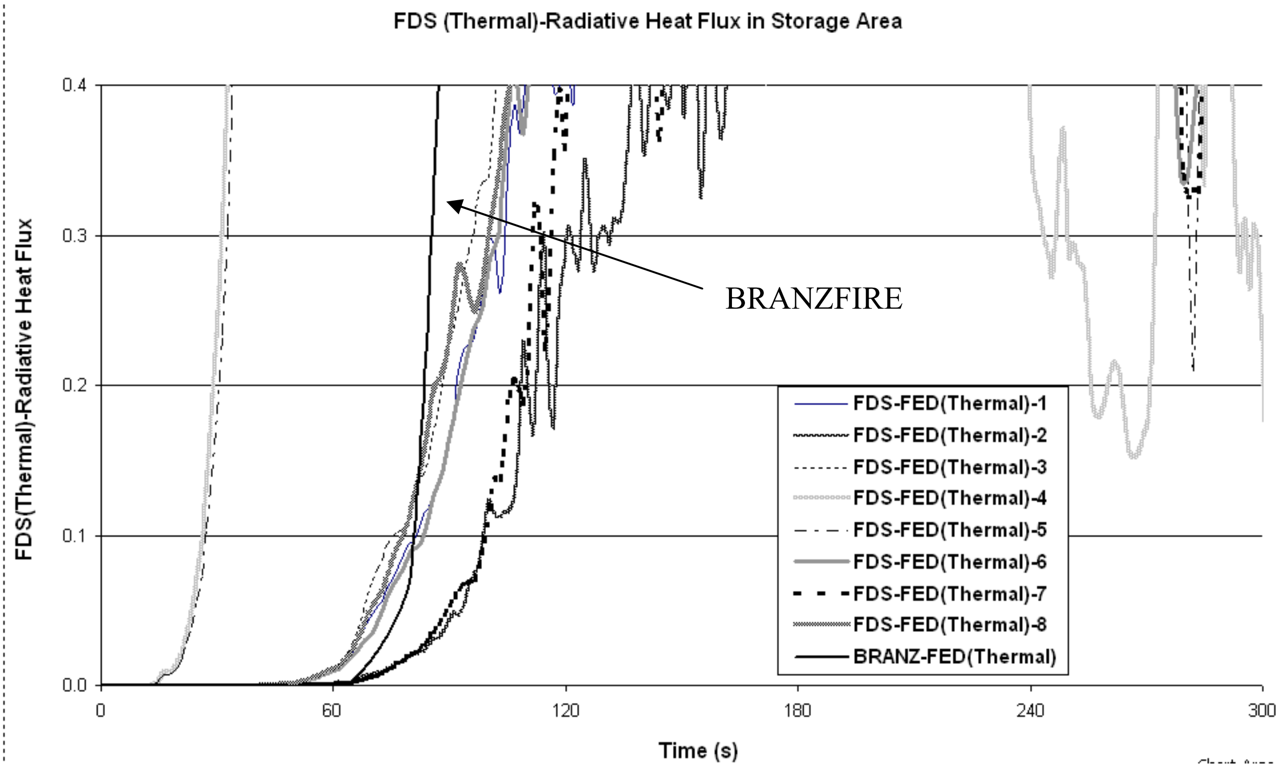
FED(CO) curves



FED thermal curves from gauge heat flux

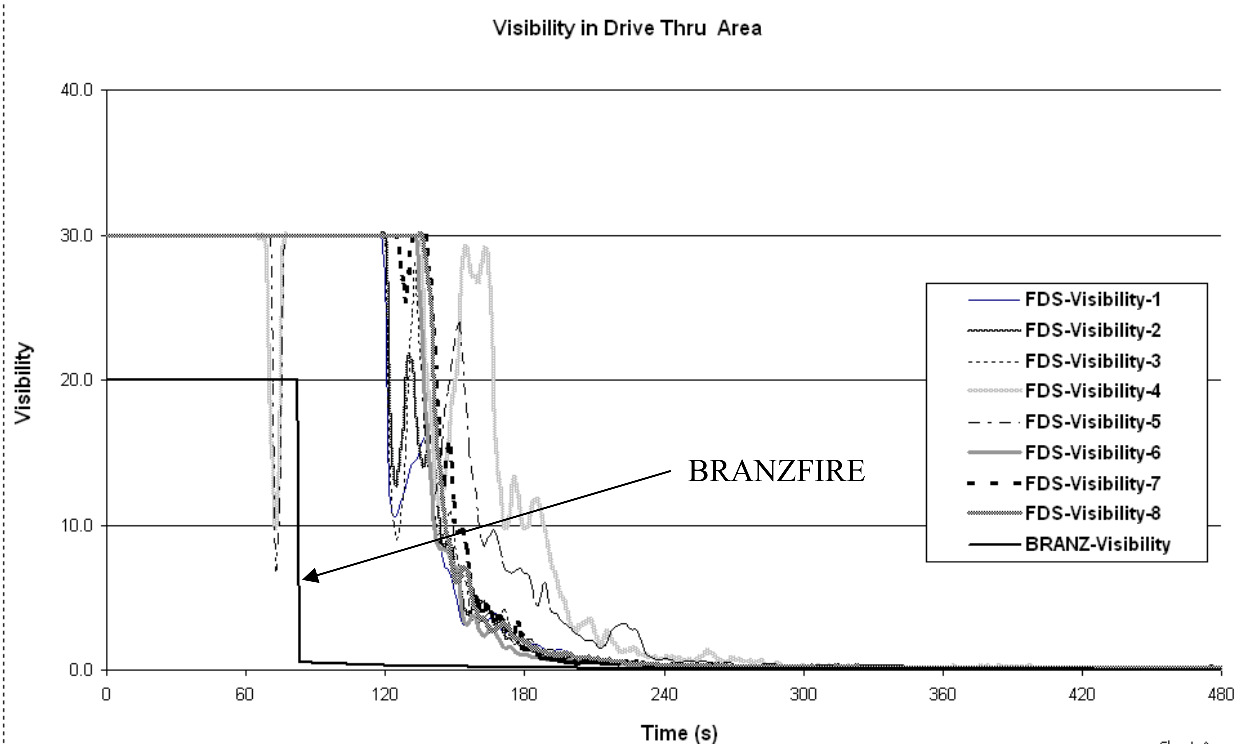


FED thermal curves from radiative heat flux

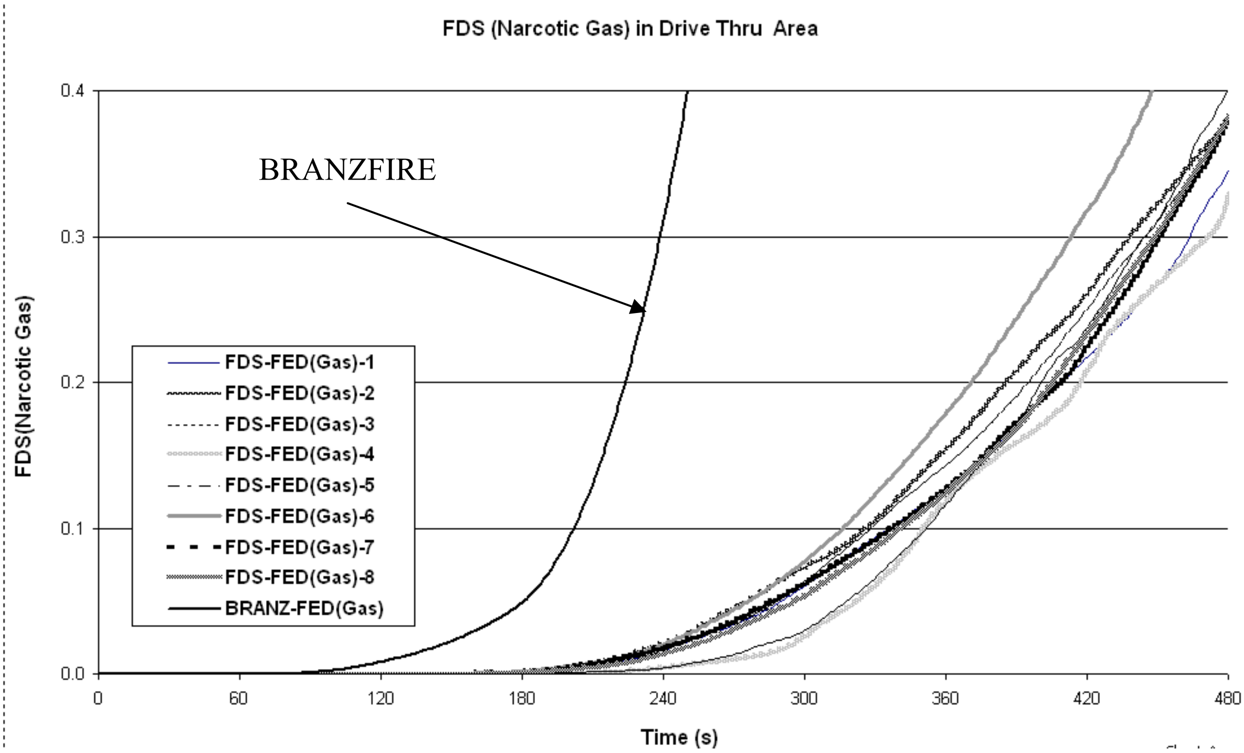


D3.2 Drive thru fire (protected with sprinkler system)

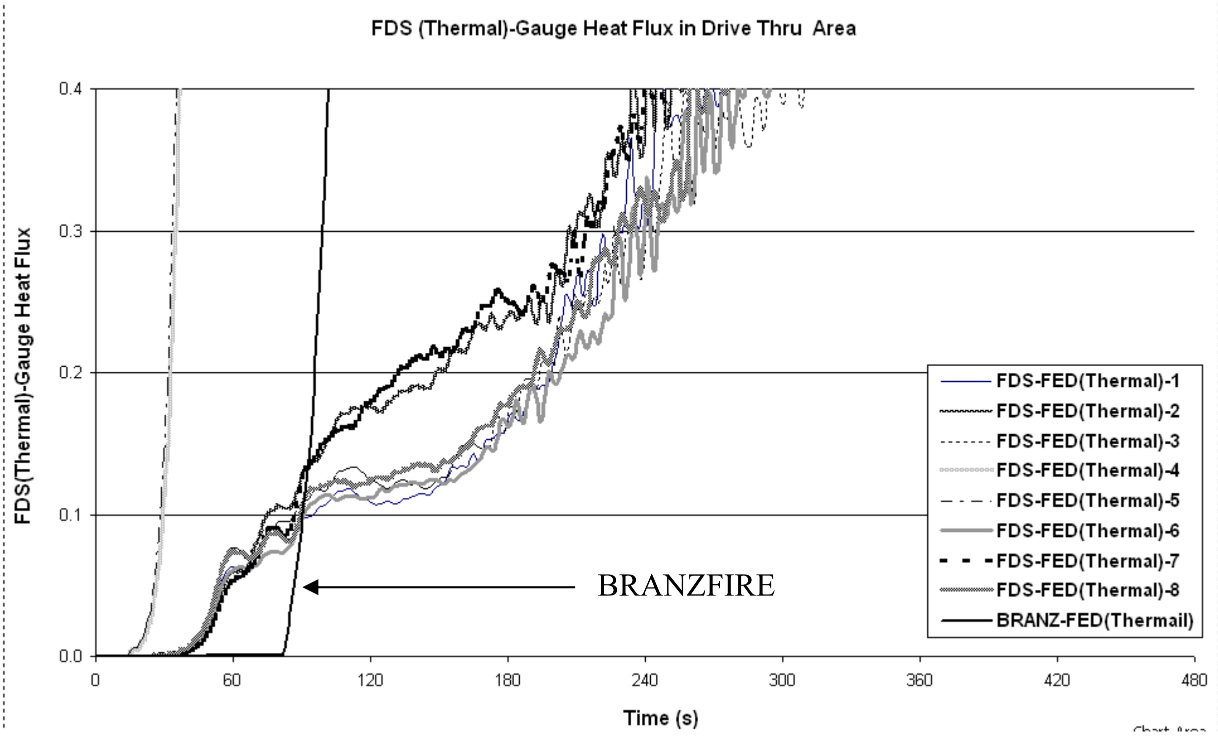
Visibility curves



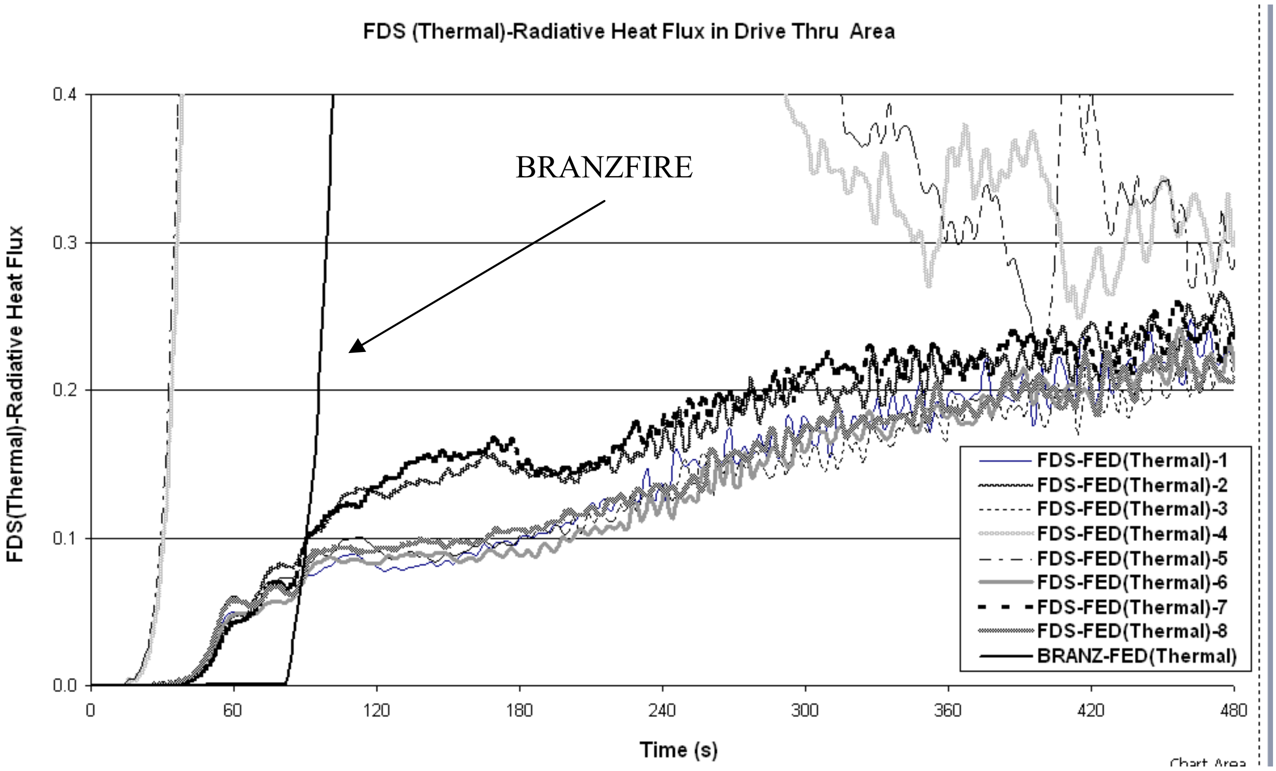
FED(CO) curves



FED thermal curves from gauge heat flux

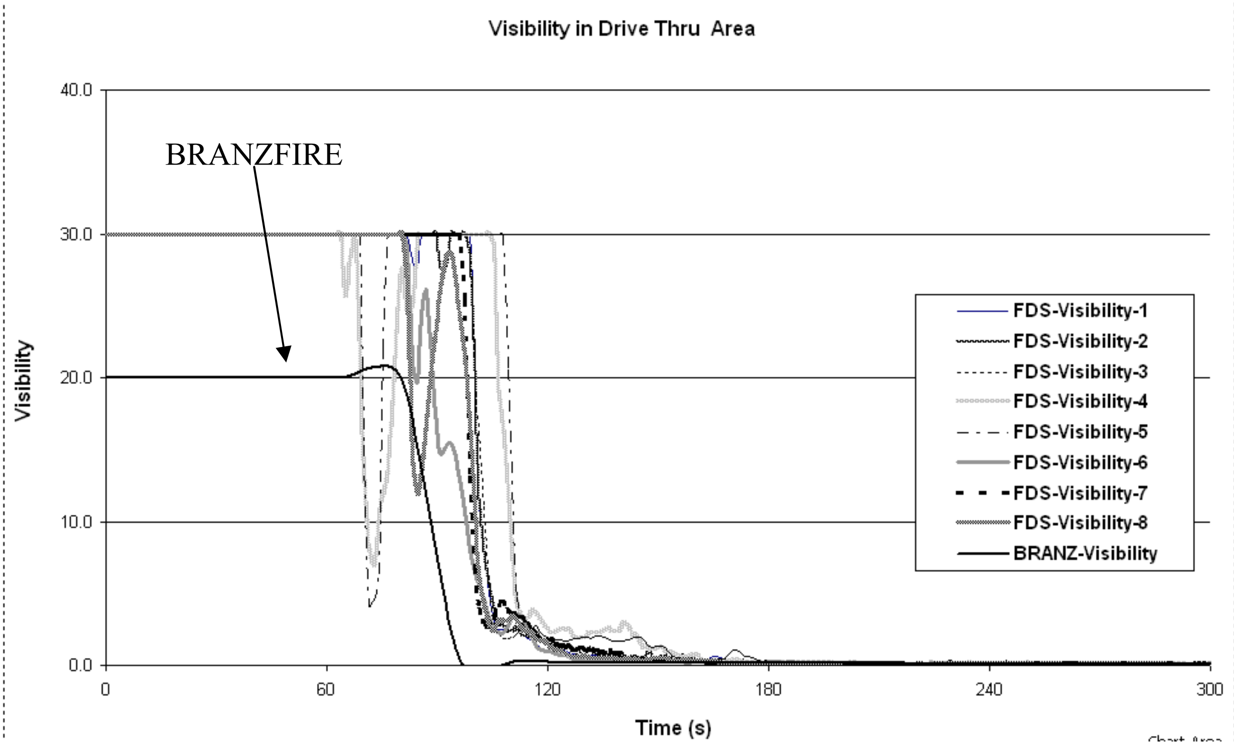


FED thermal curves from radiative heat flux

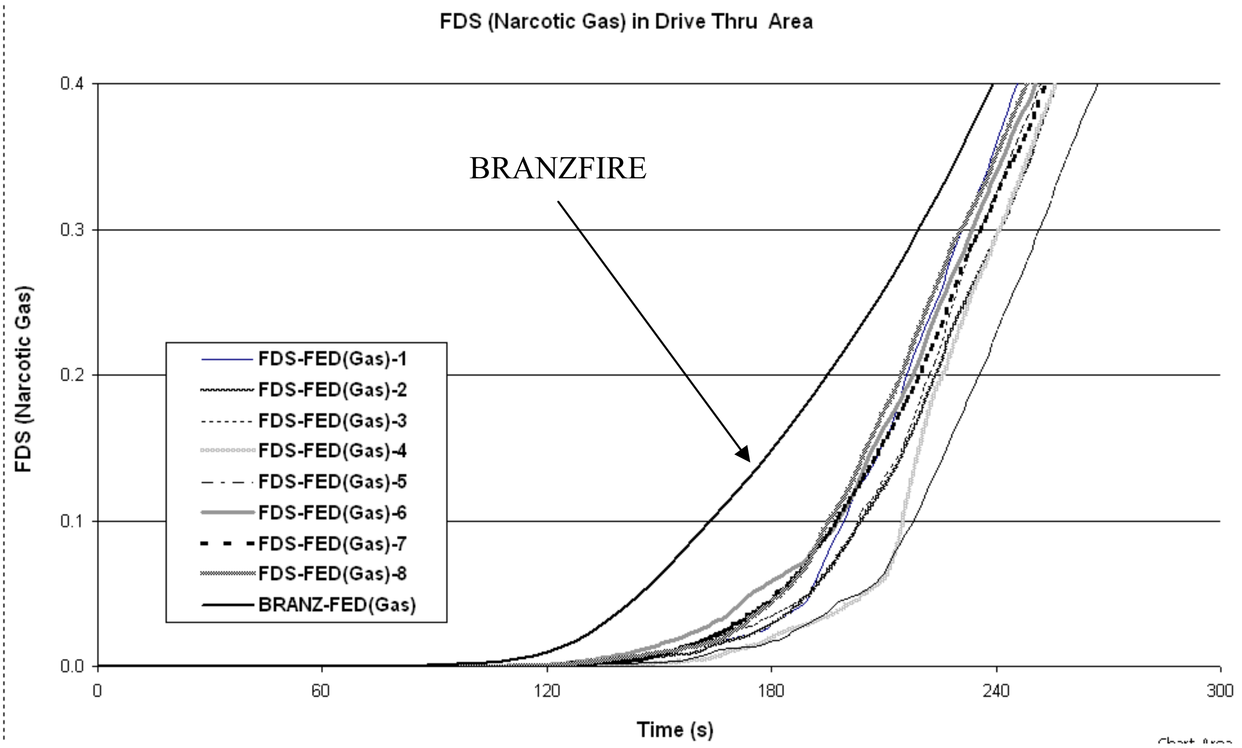


D3.3 Drive thru fire (not protected with sprinkler system)

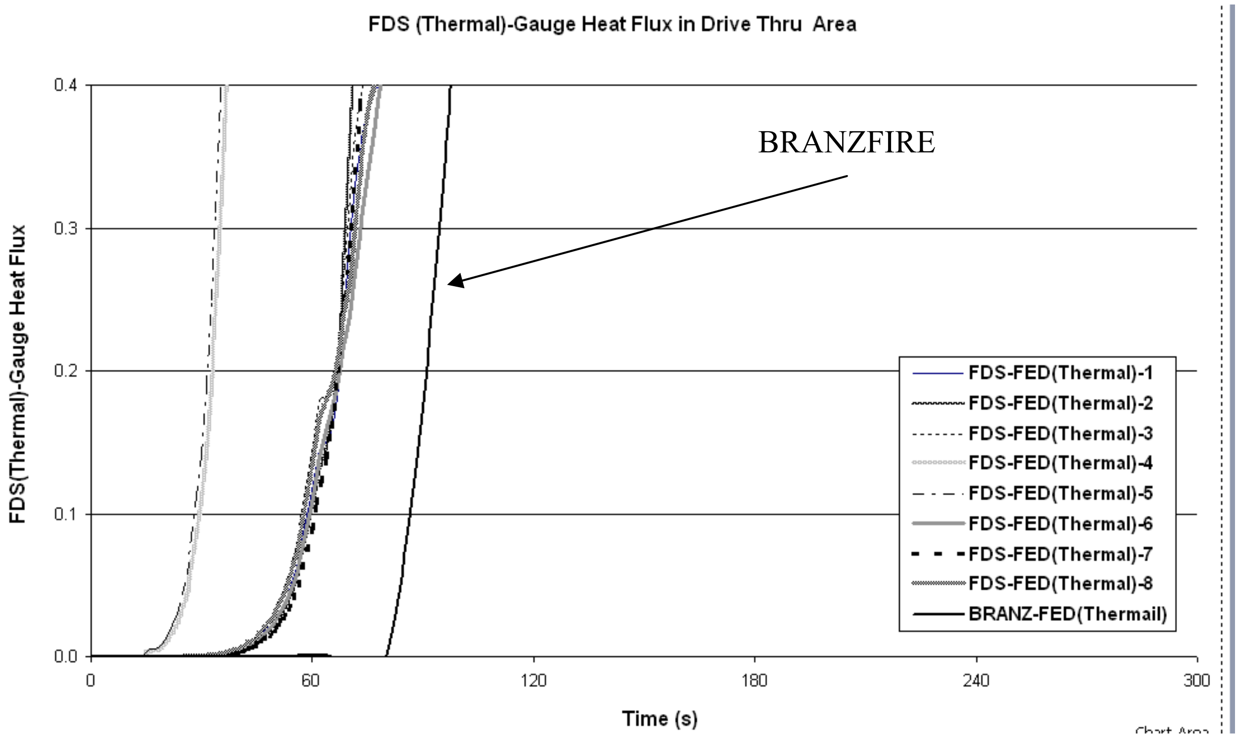
Visibility curves



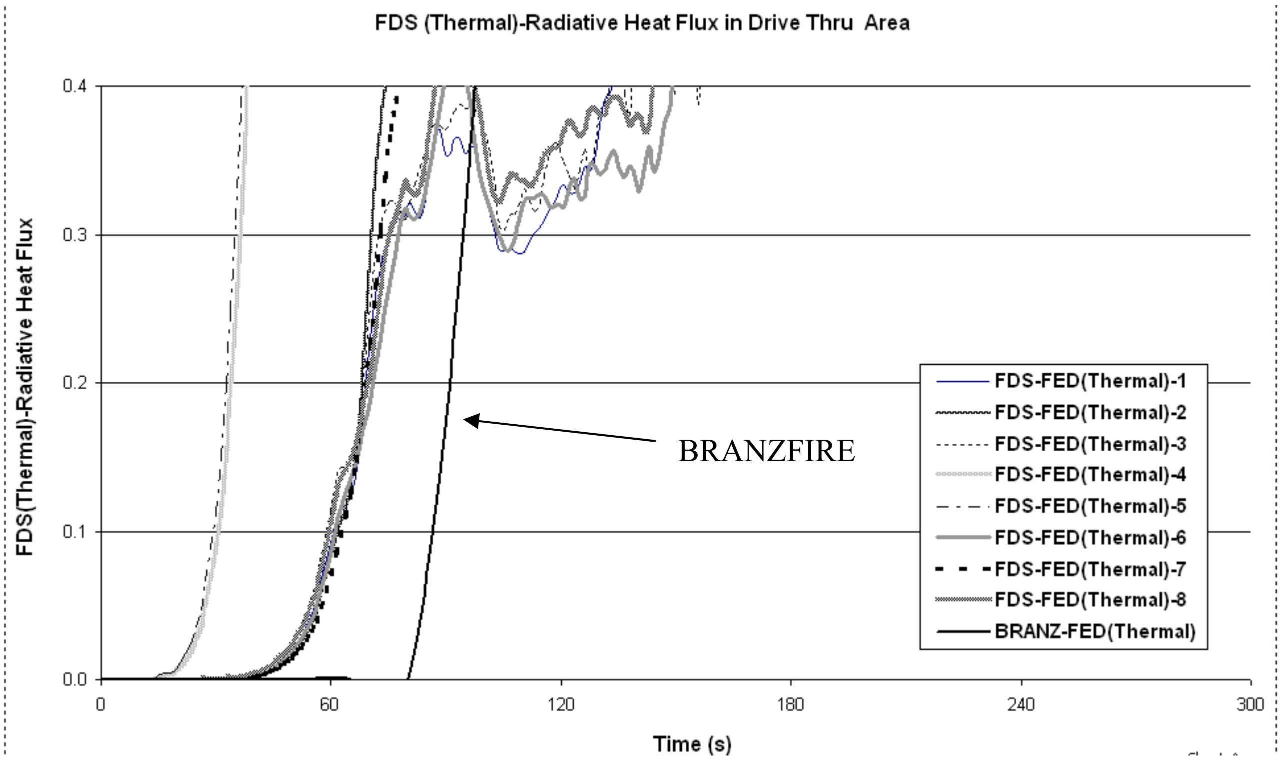
FED(CO) curves



FED thermal curves from gauge heat flux

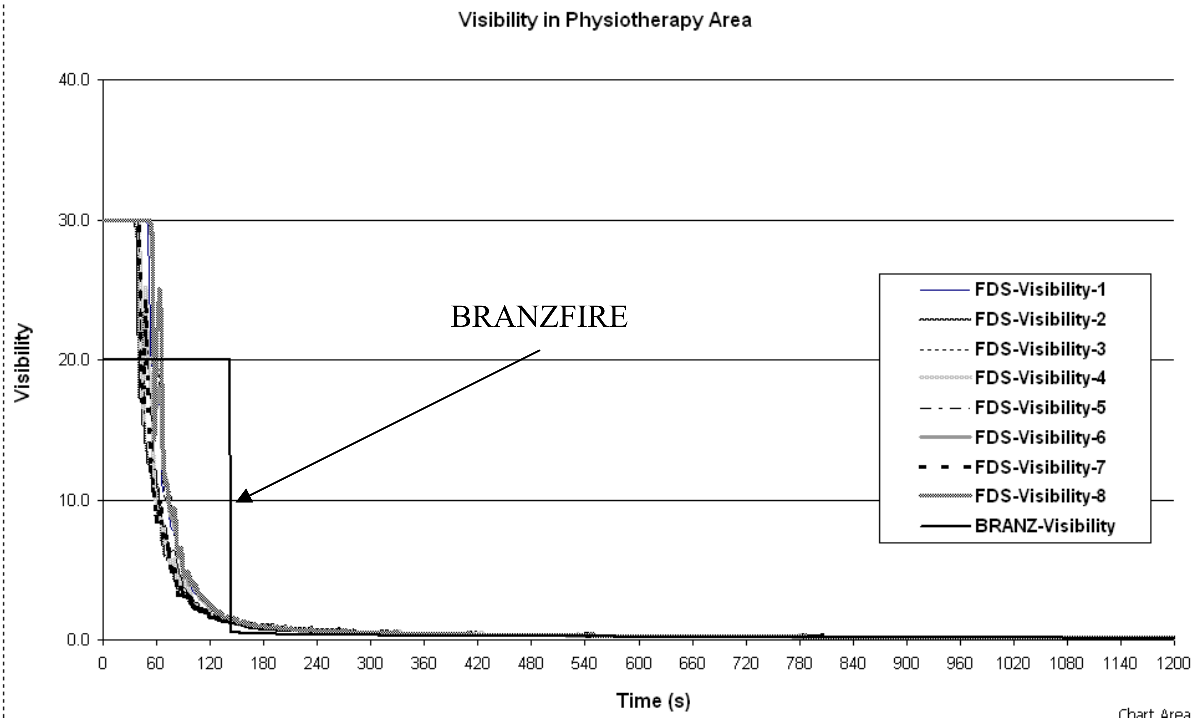


FED thermal curves from radiative heat flux

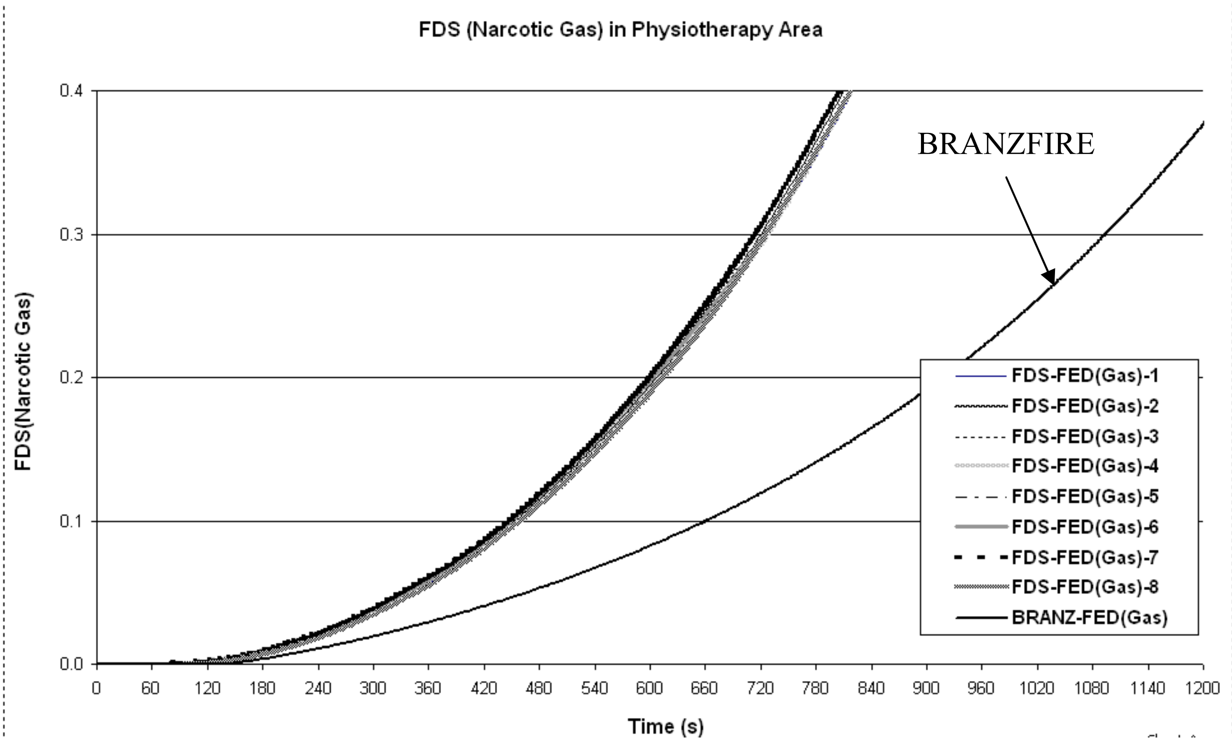


D3.4 Physiotherapy fire (protected with sprinkler system)

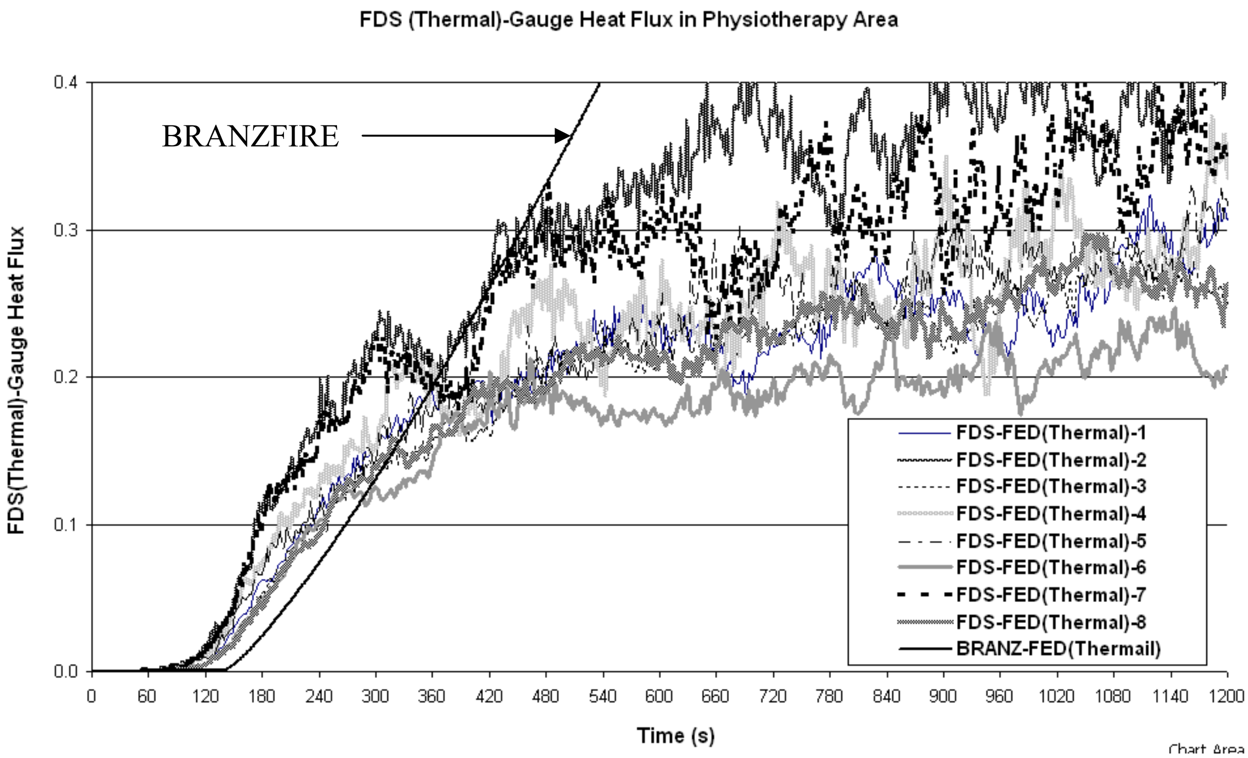
Visibility curves



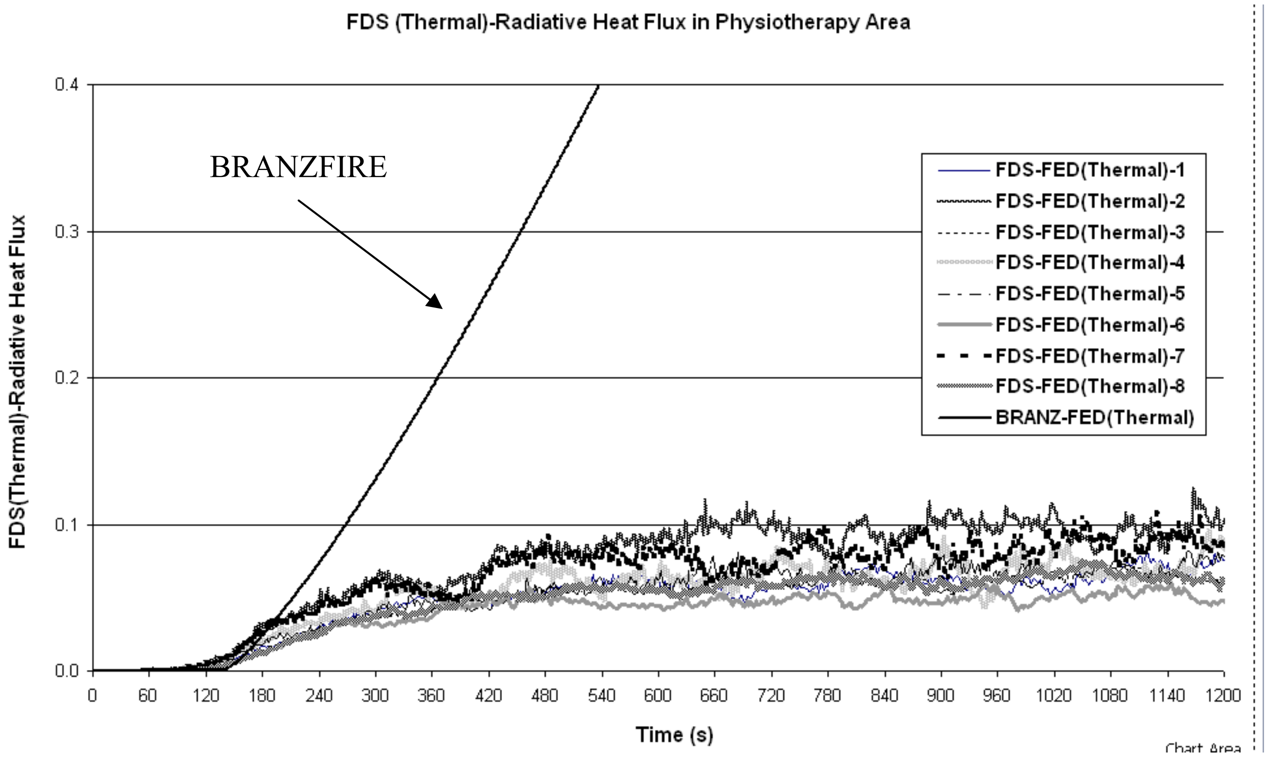
FED(CO) curves



FED thermal curves from gauge heat flux

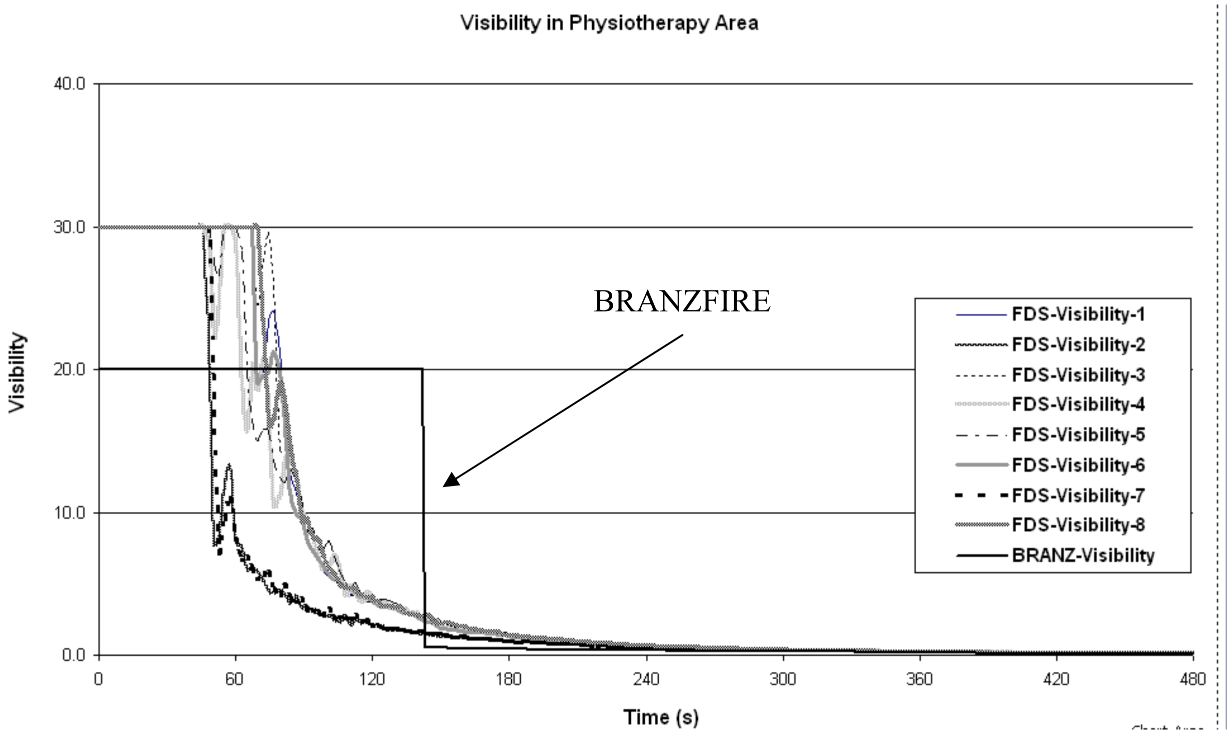


FED thermal curves from radiative heat flux

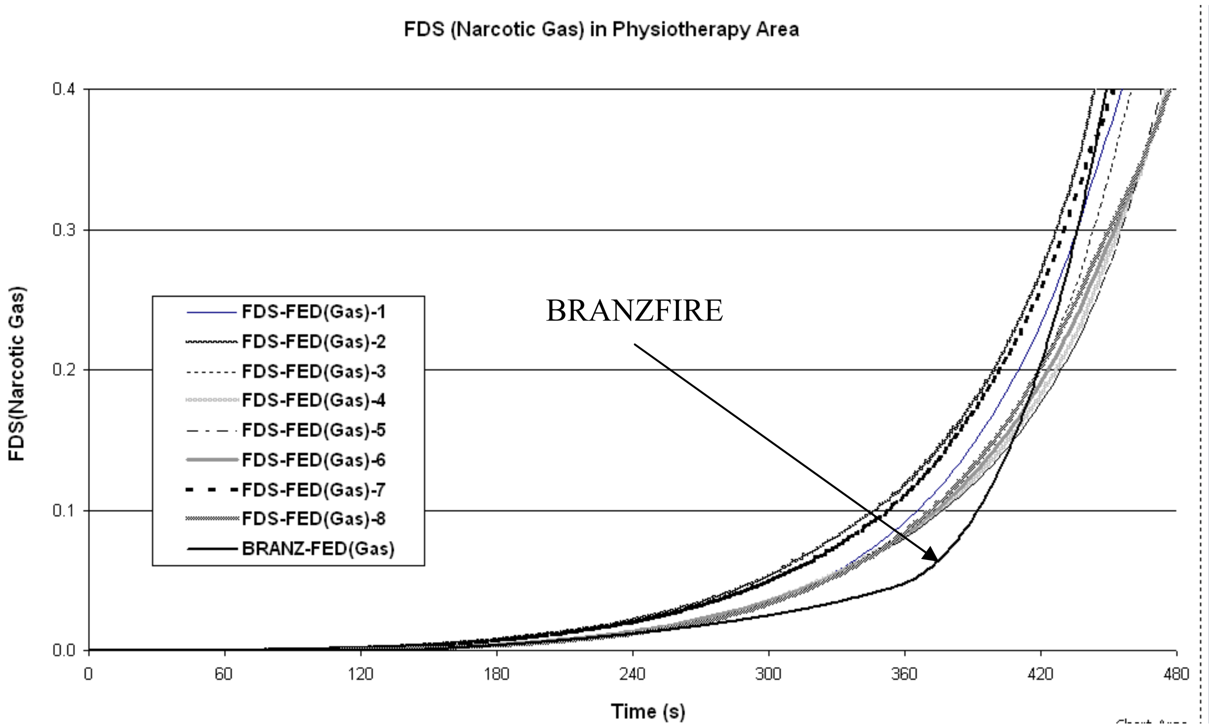


D3.5 Physiotherapy fire (not protected with sprinkler system)

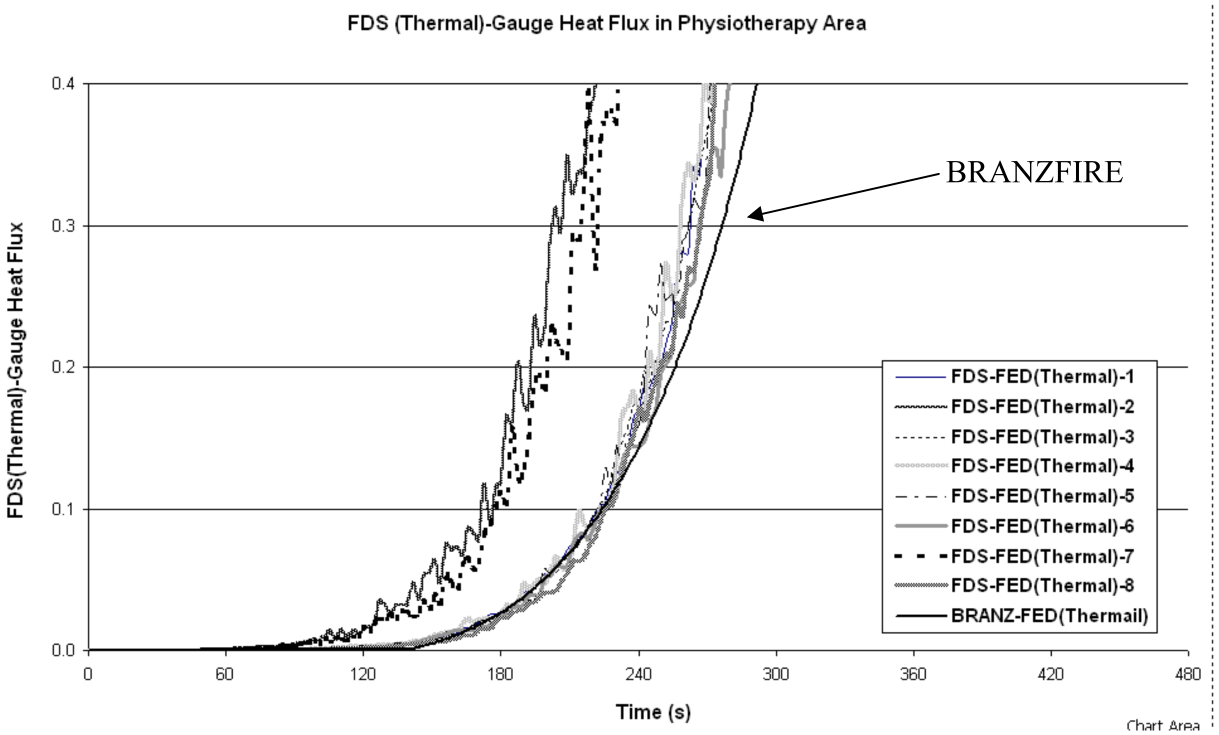
Visibility curves



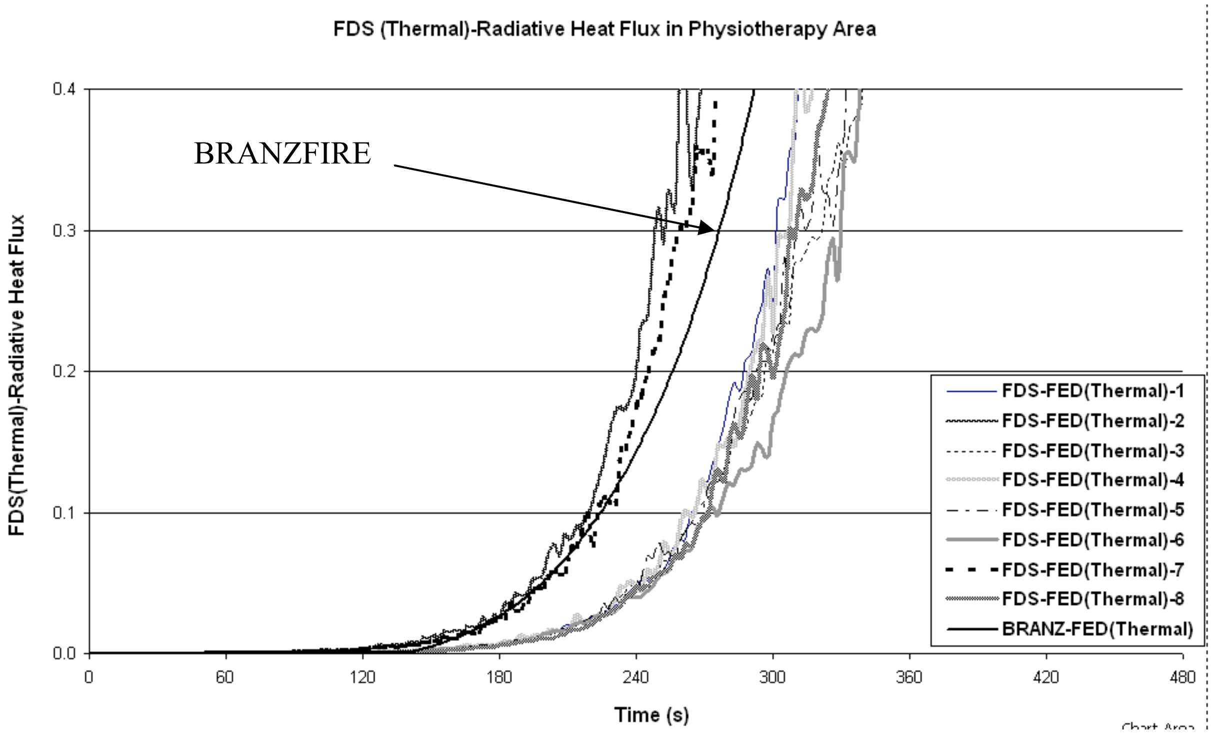
FED(CO) curves



FED thermal curves from gauge heat flux

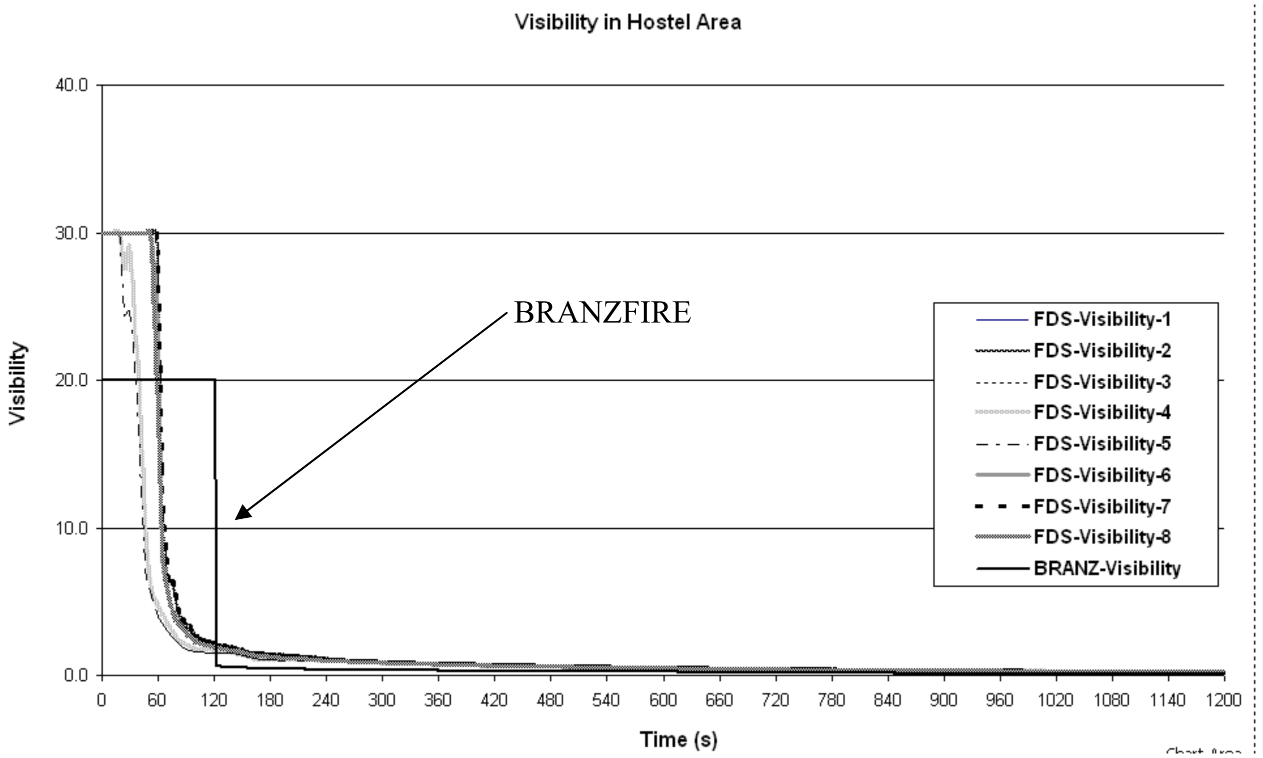


FED thermal curves from radiative heat flux

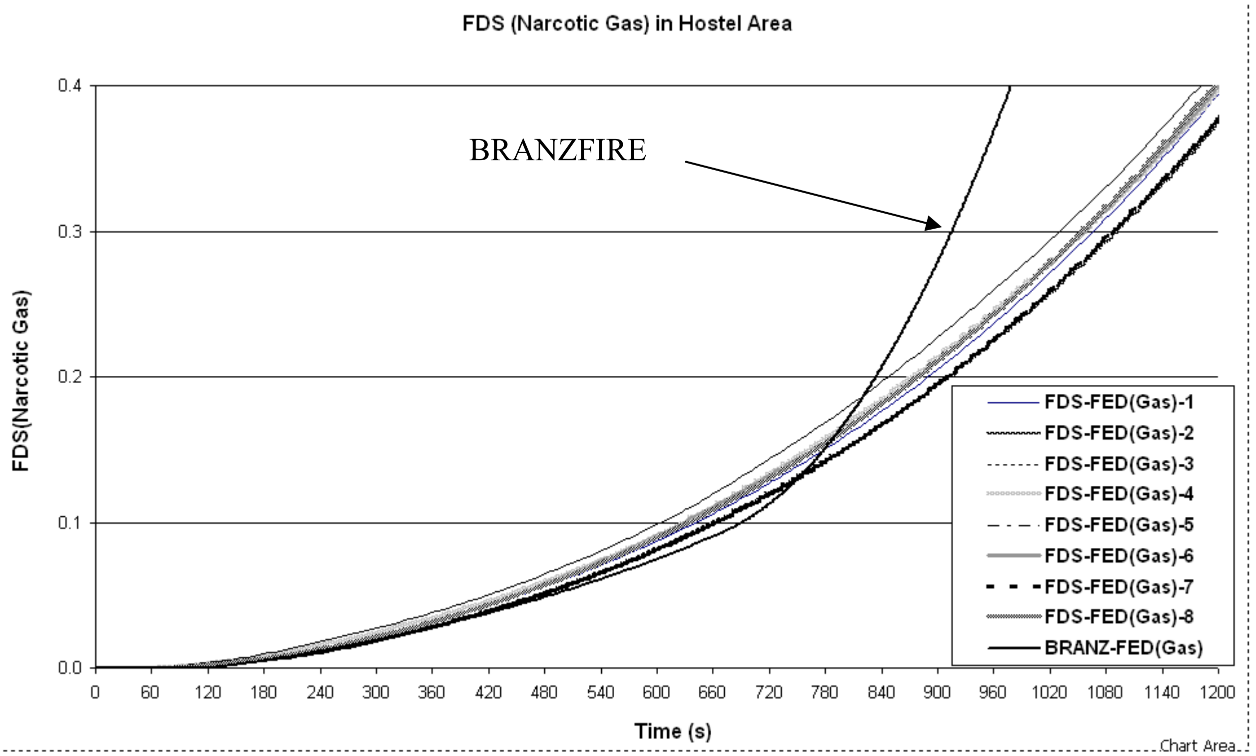


D3.6 Hostel fire (protected with sprinkler system)

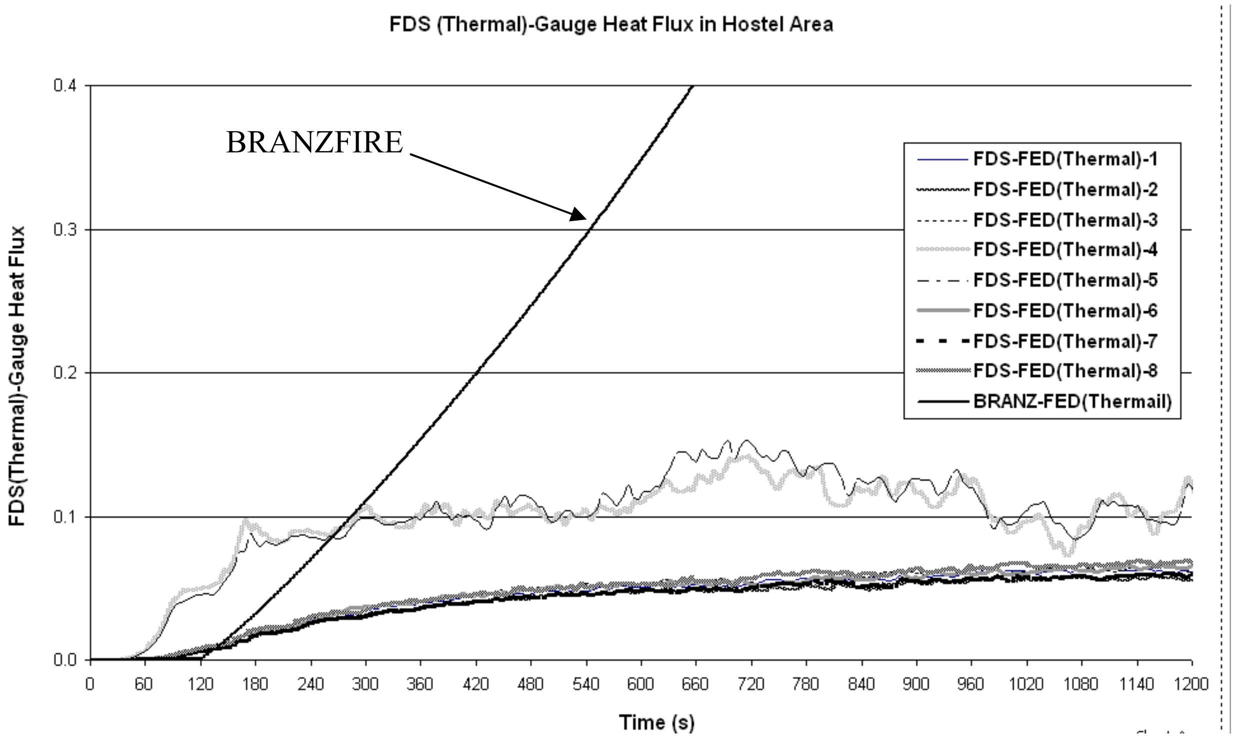
Visibility curves



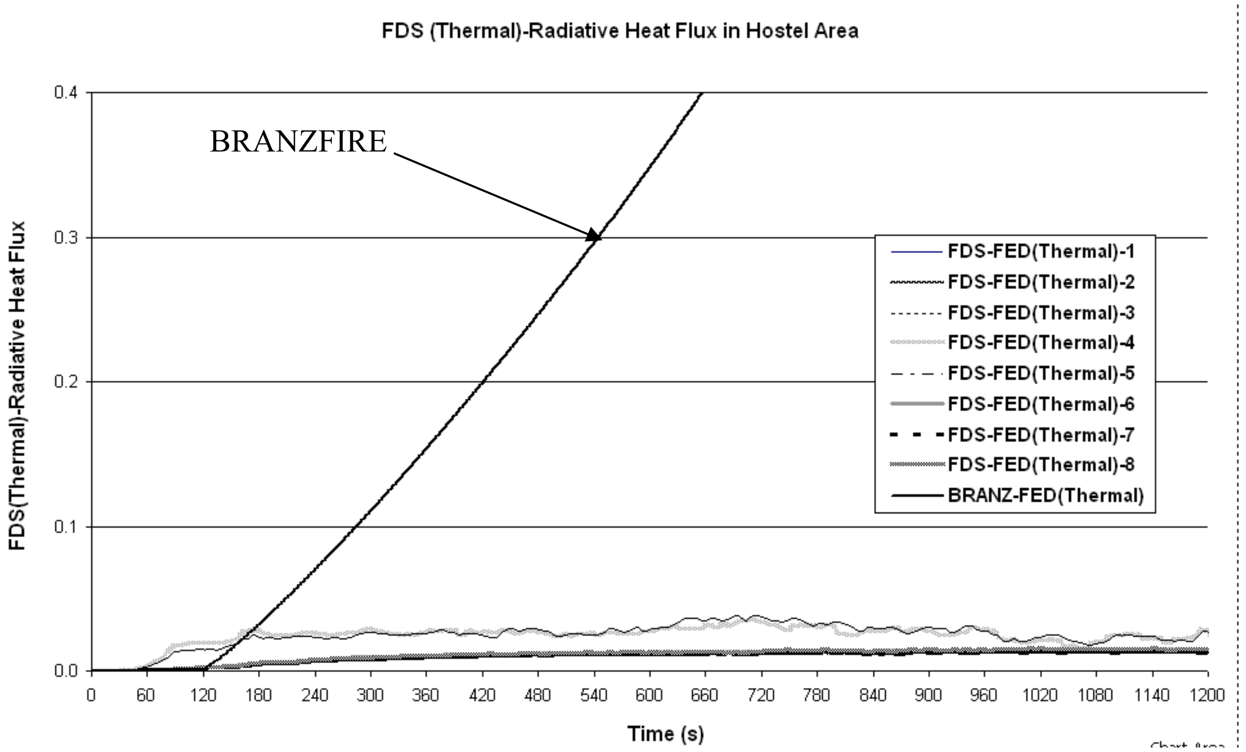
FED(CO) curves



FED thermal curves from gauge heat flux

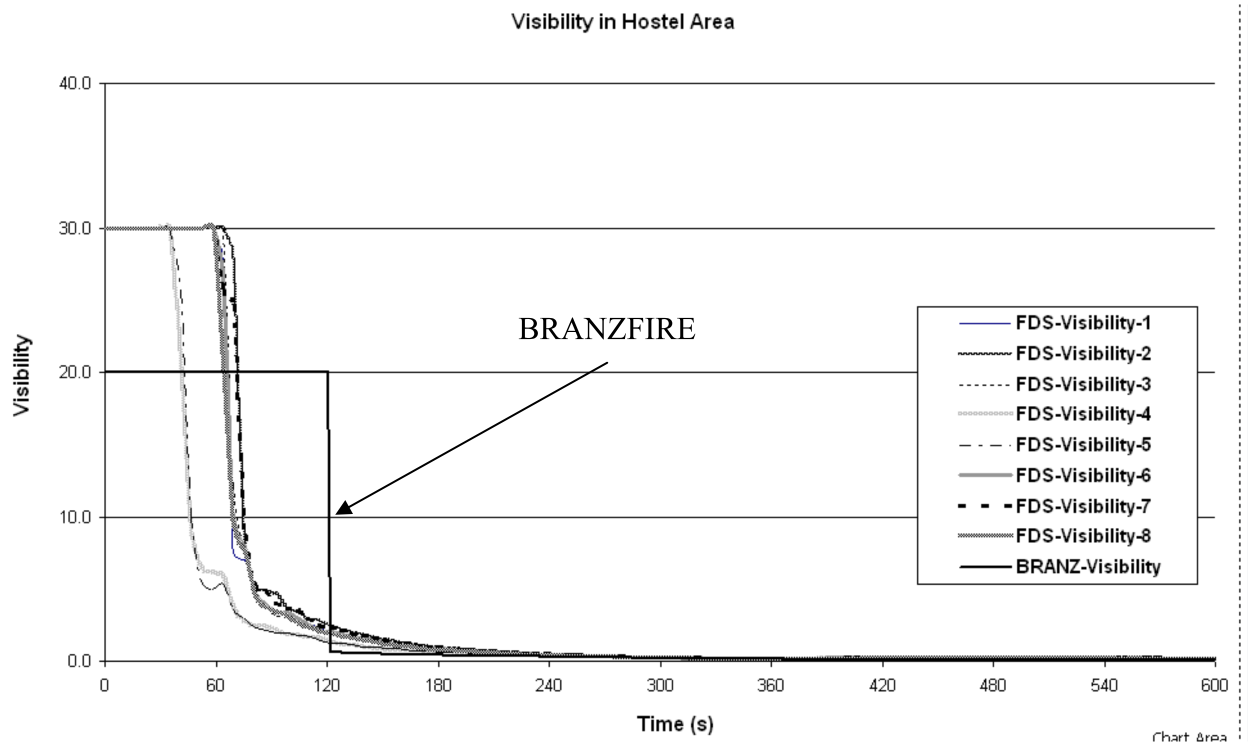


FED thermal curves from radiative heat flux

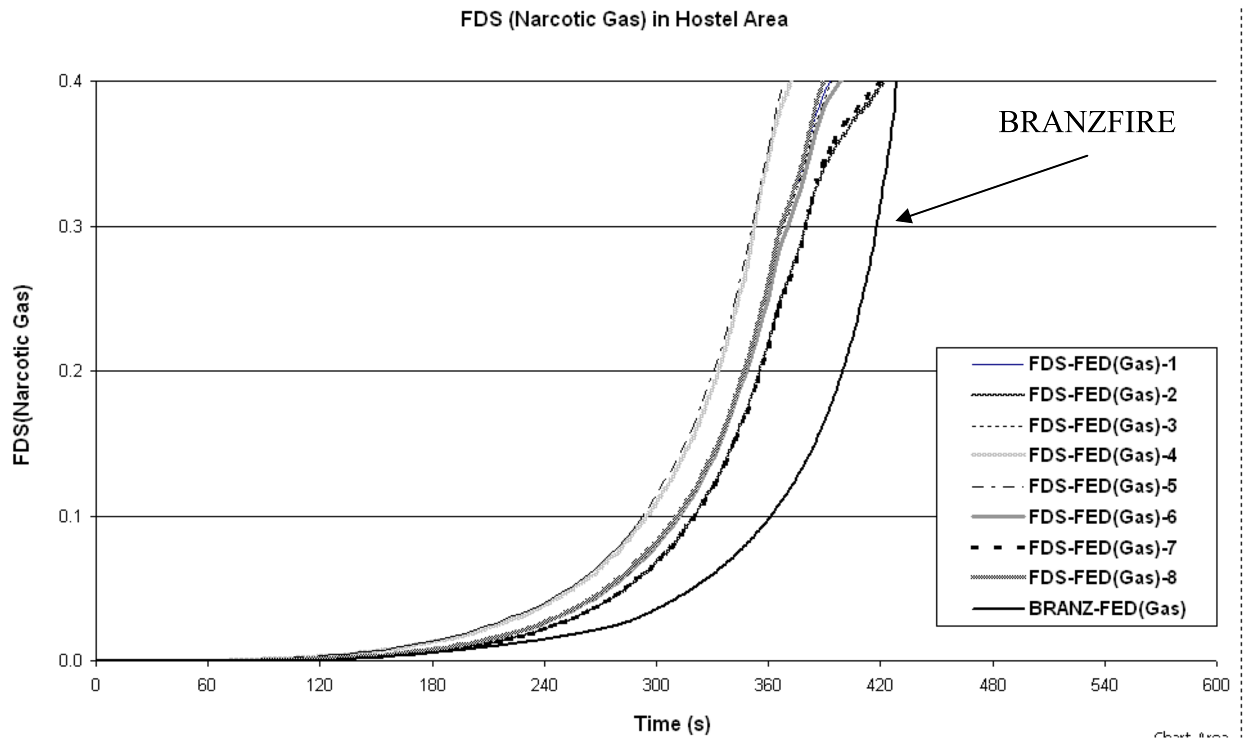


D3.7 Hostel fire (Not protected with sprinkler system)

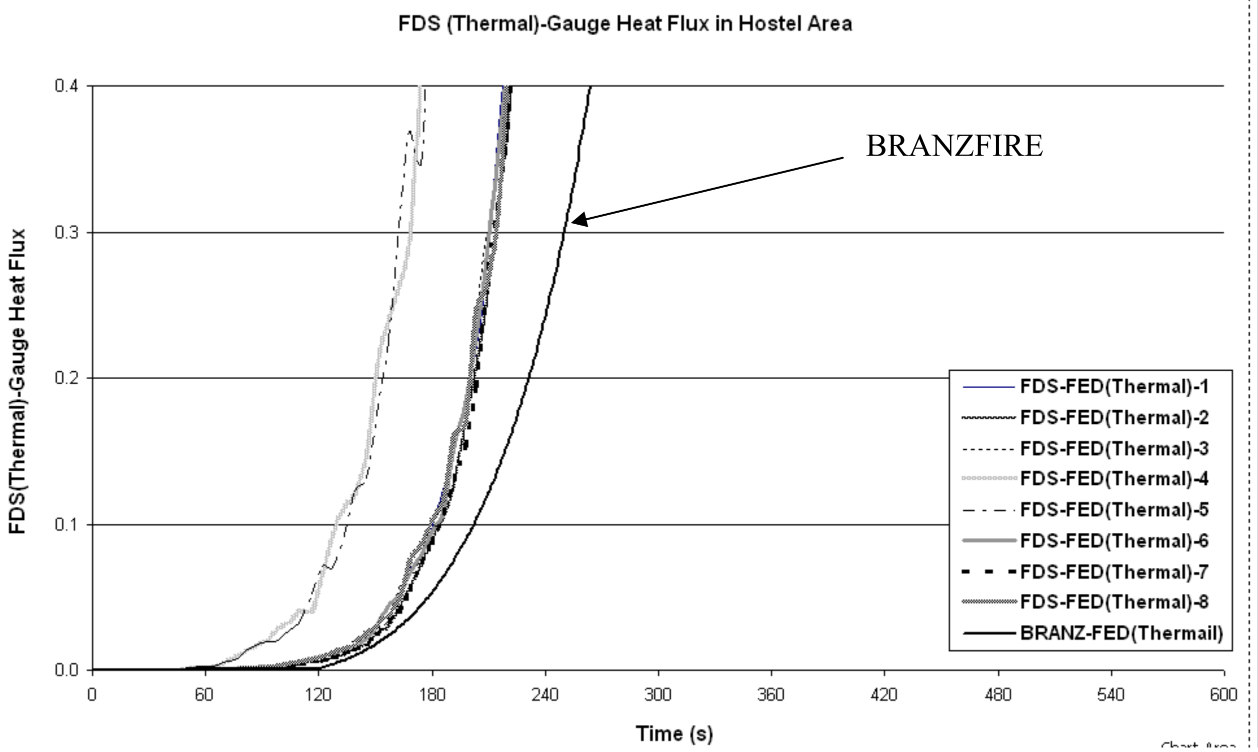
Visibility curves



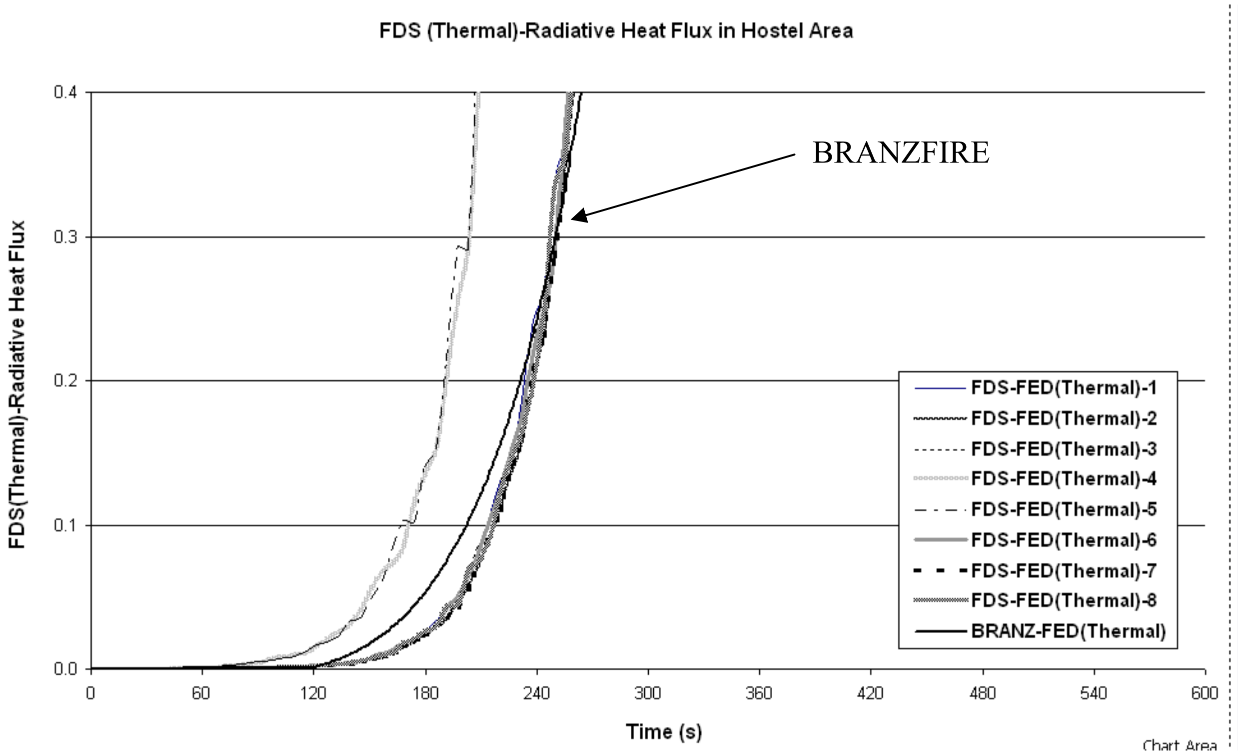
FED(CO) curves



FED thermal curves from gauge heat flux

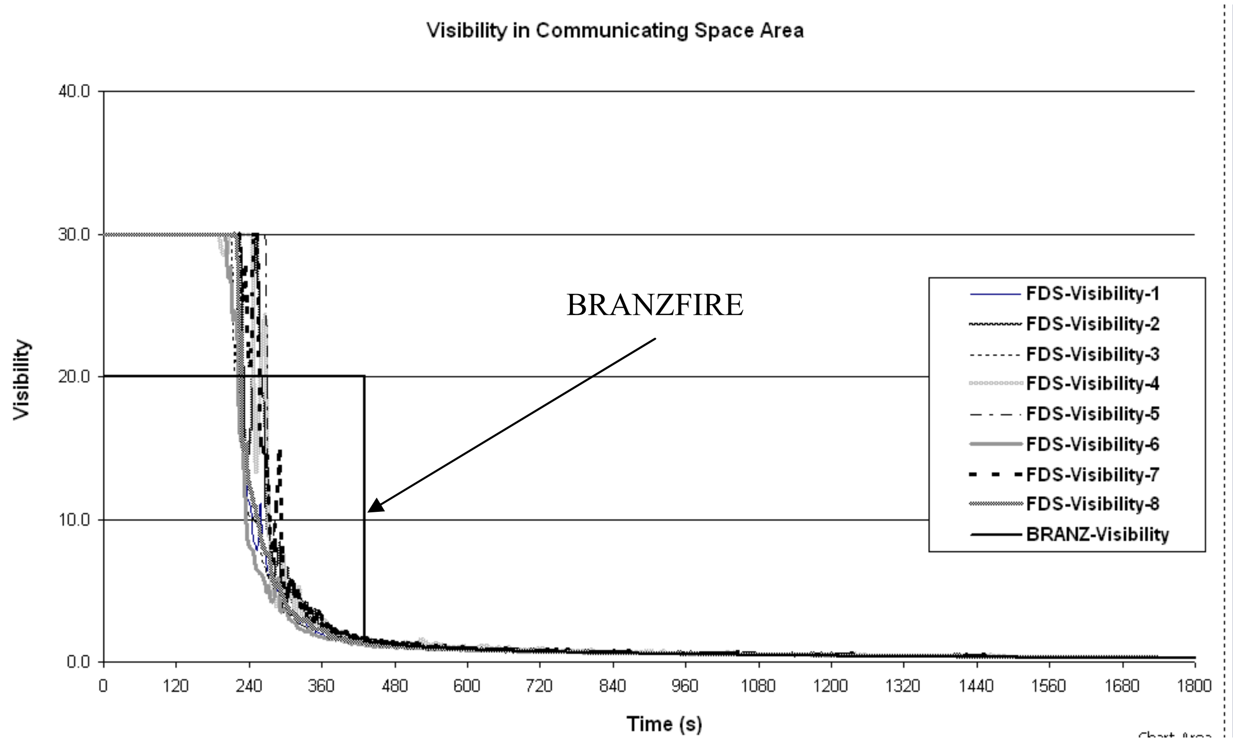


FED thermal curves from radiative heat flux

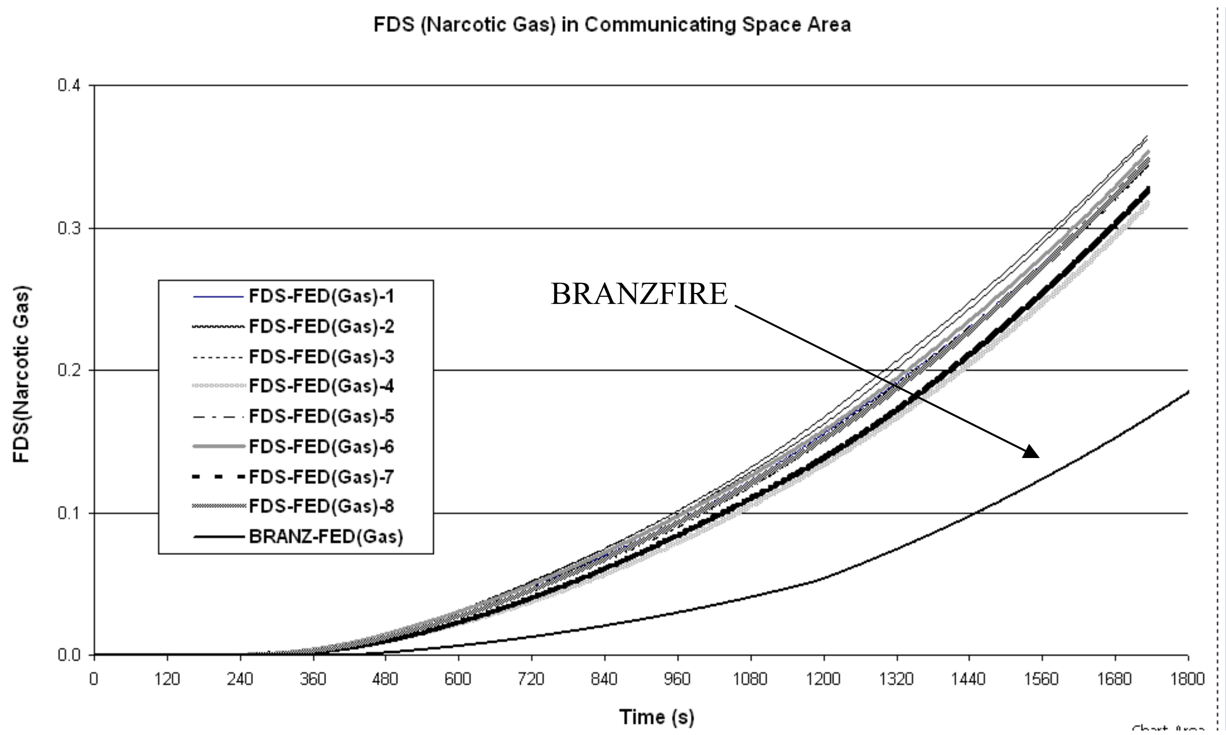


D3.8 Communicating space fire (protected with sprinkler system)

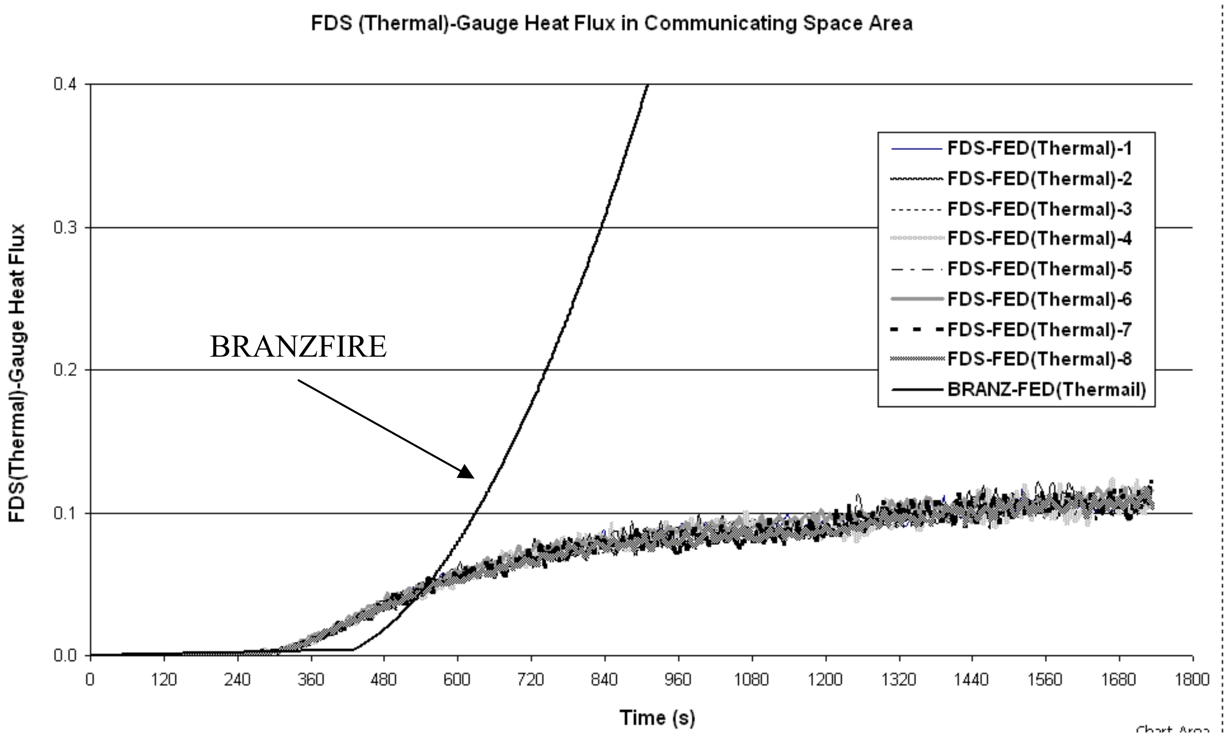
Visibility curves



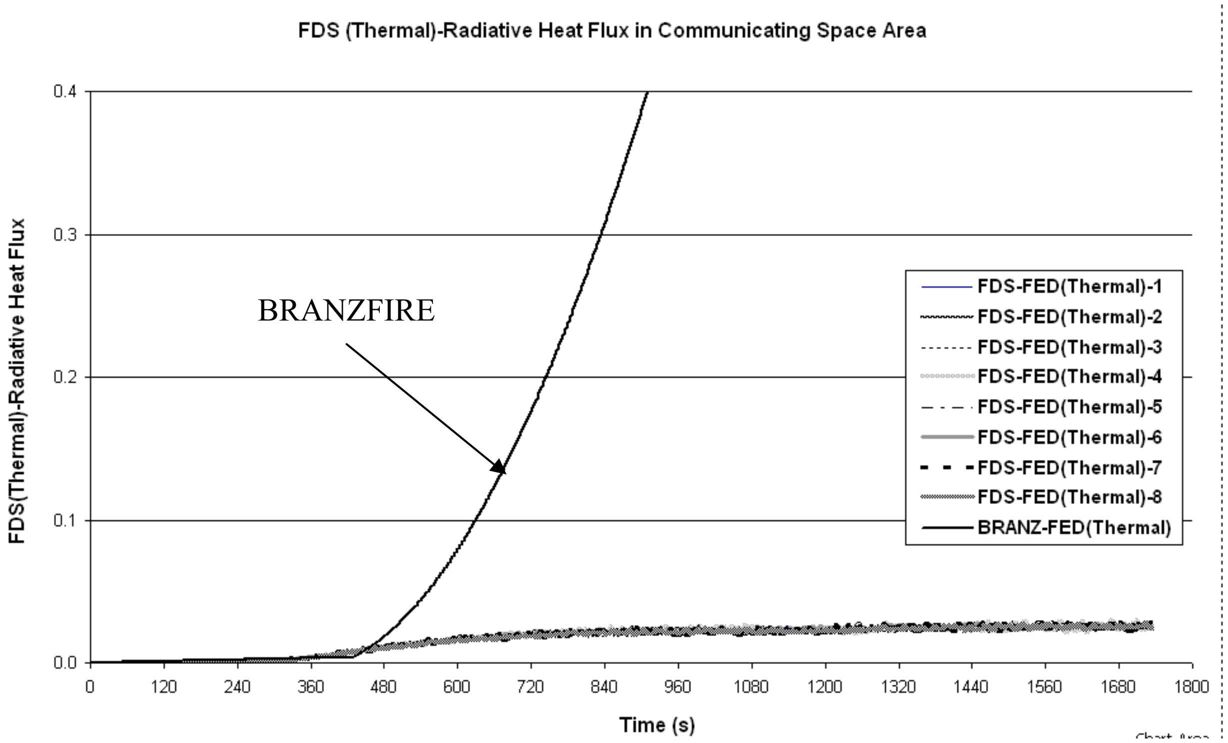
FED(CO) curves



FED thermal curves from gauge heat flux

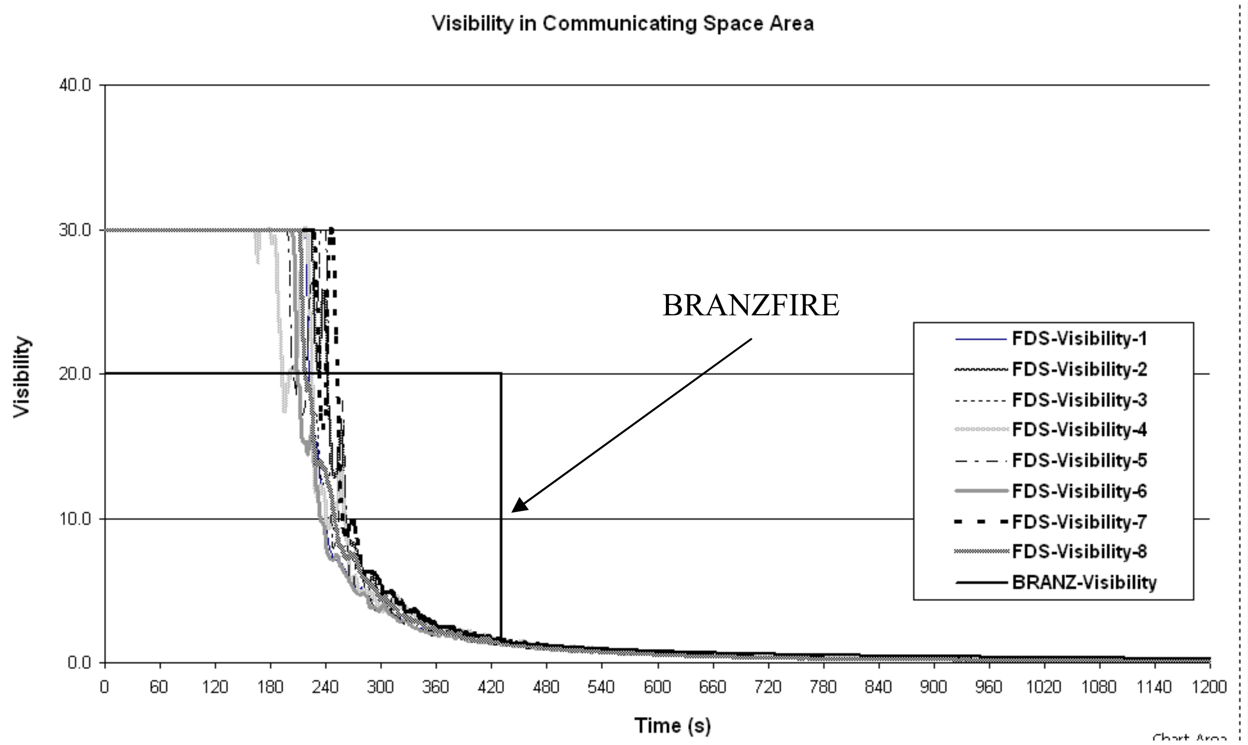


FED thermal curves from radiative heat flux

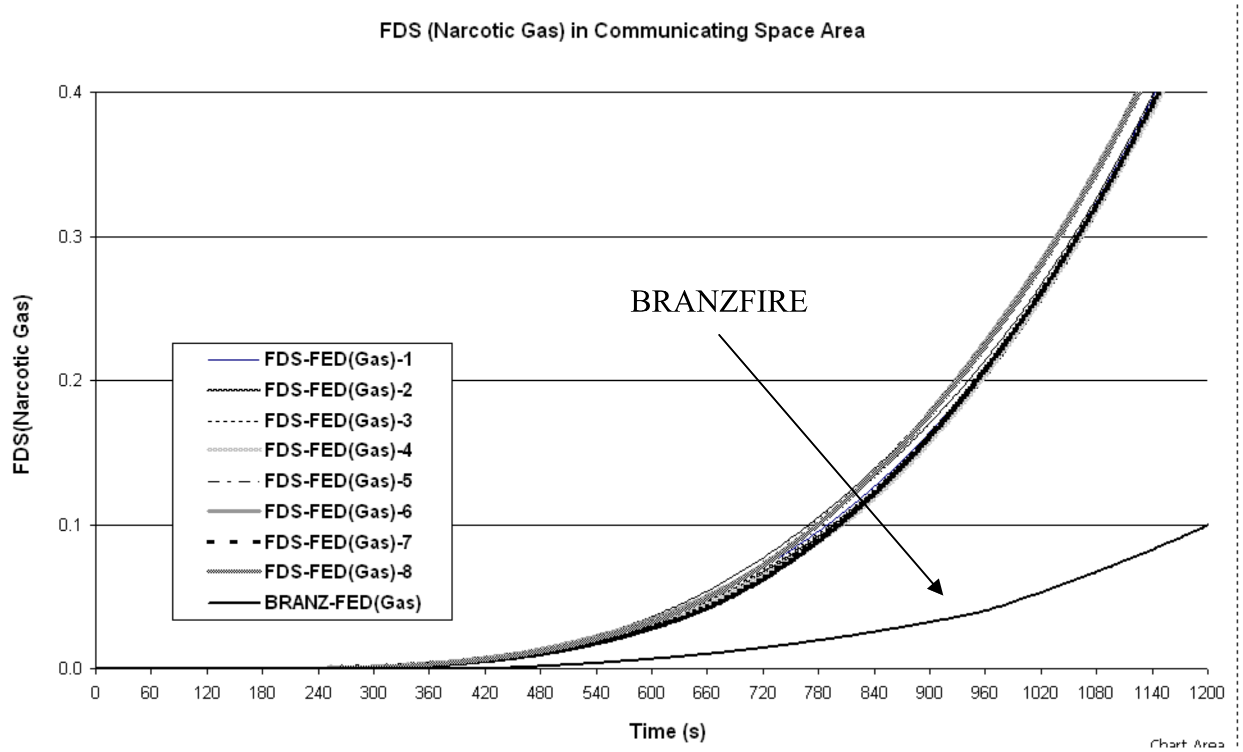


D3.9 Communicating space fire (not protected with sprinkler system)

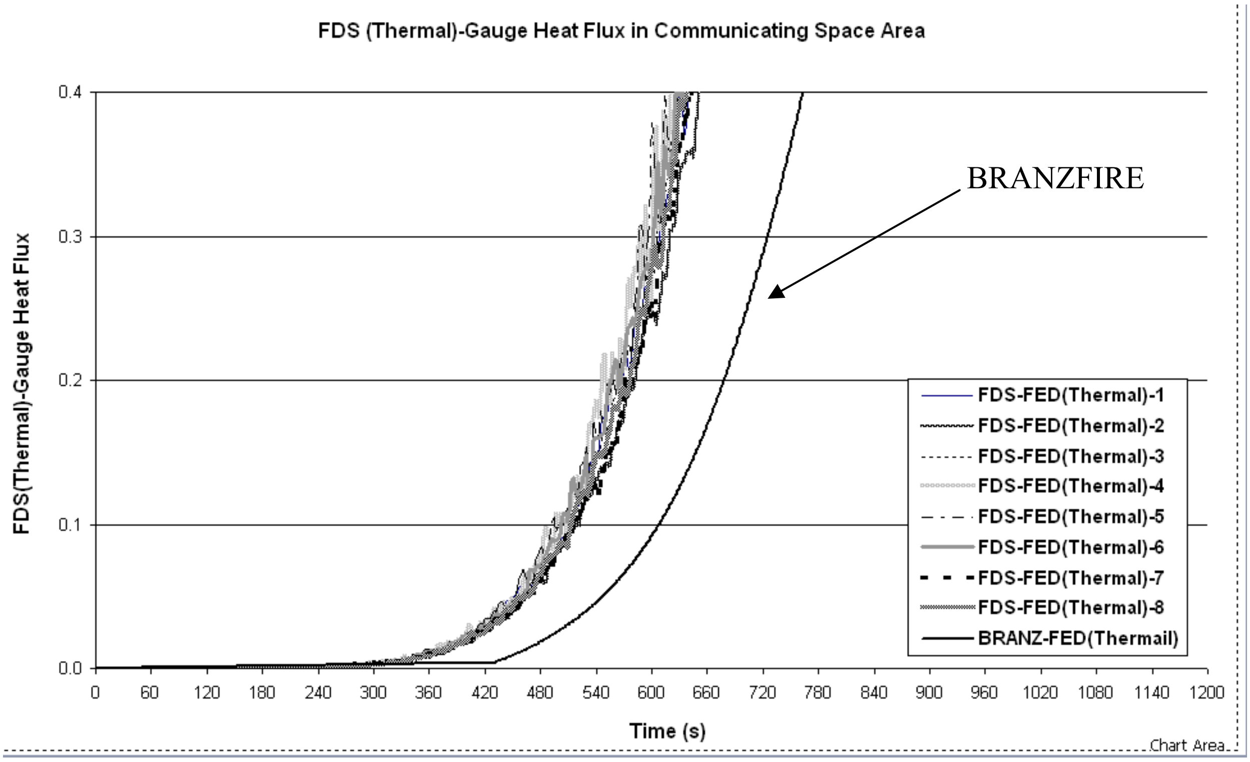
Visibility curves



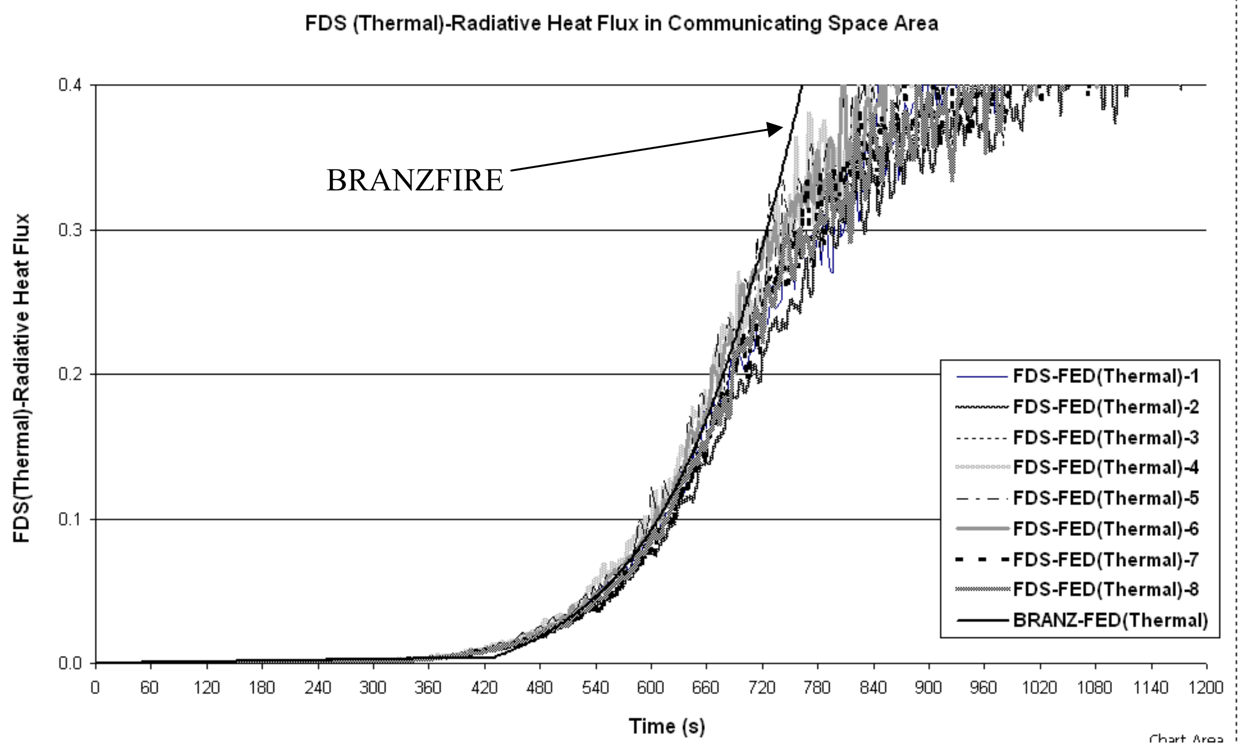
FED(CO) curves



FED thermal curves from gauge heat flux

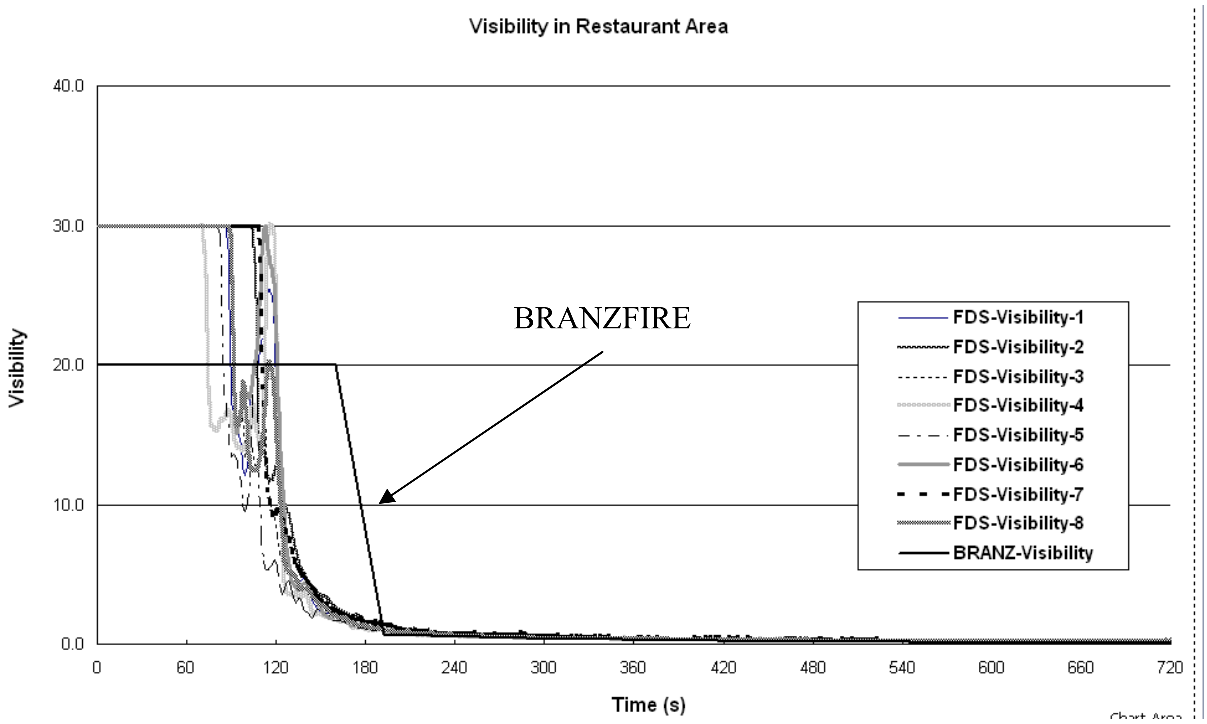


FED thermal curves from radiative heat flux

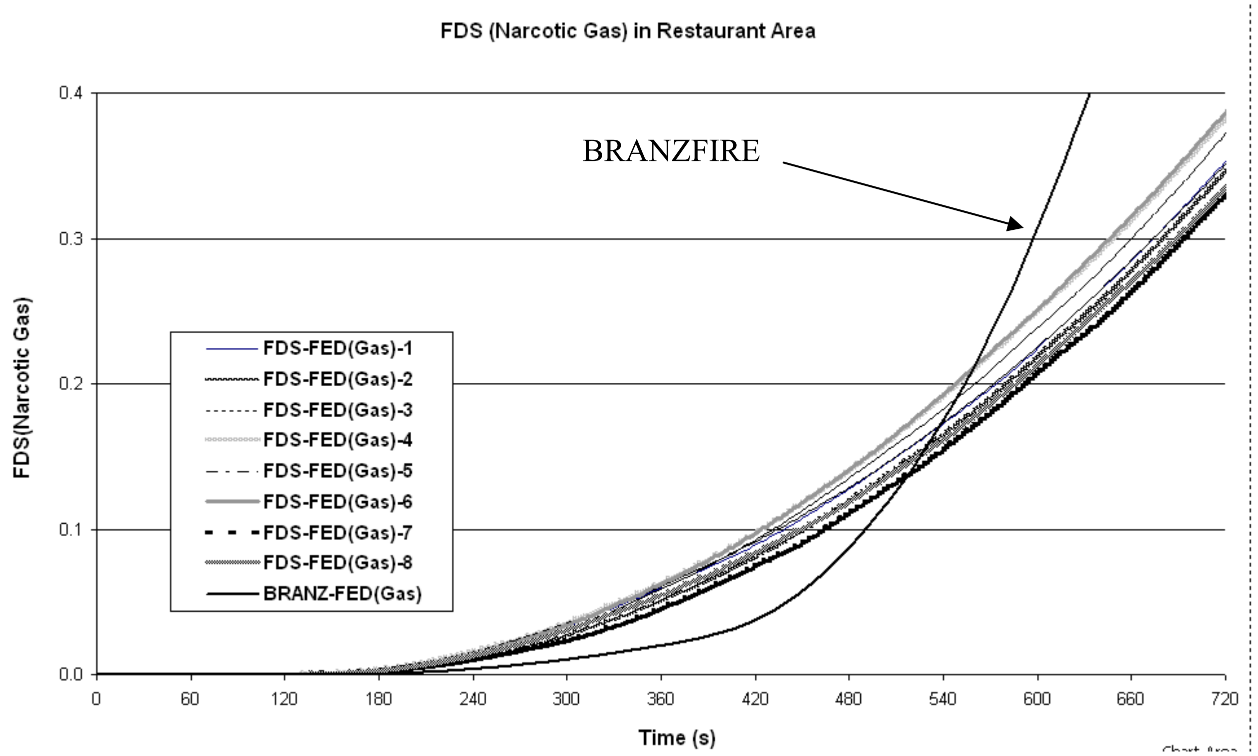


D3.10 Restaurant fire (protected with sprinkler system)

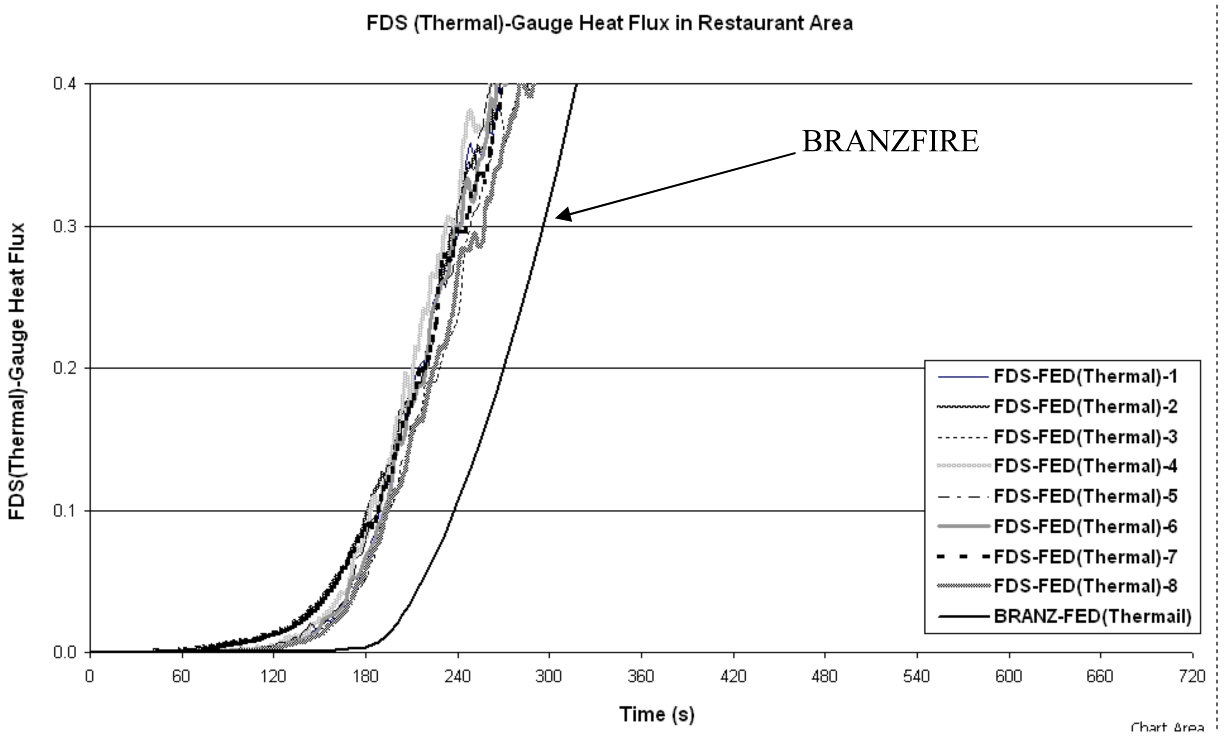
Visibility curves



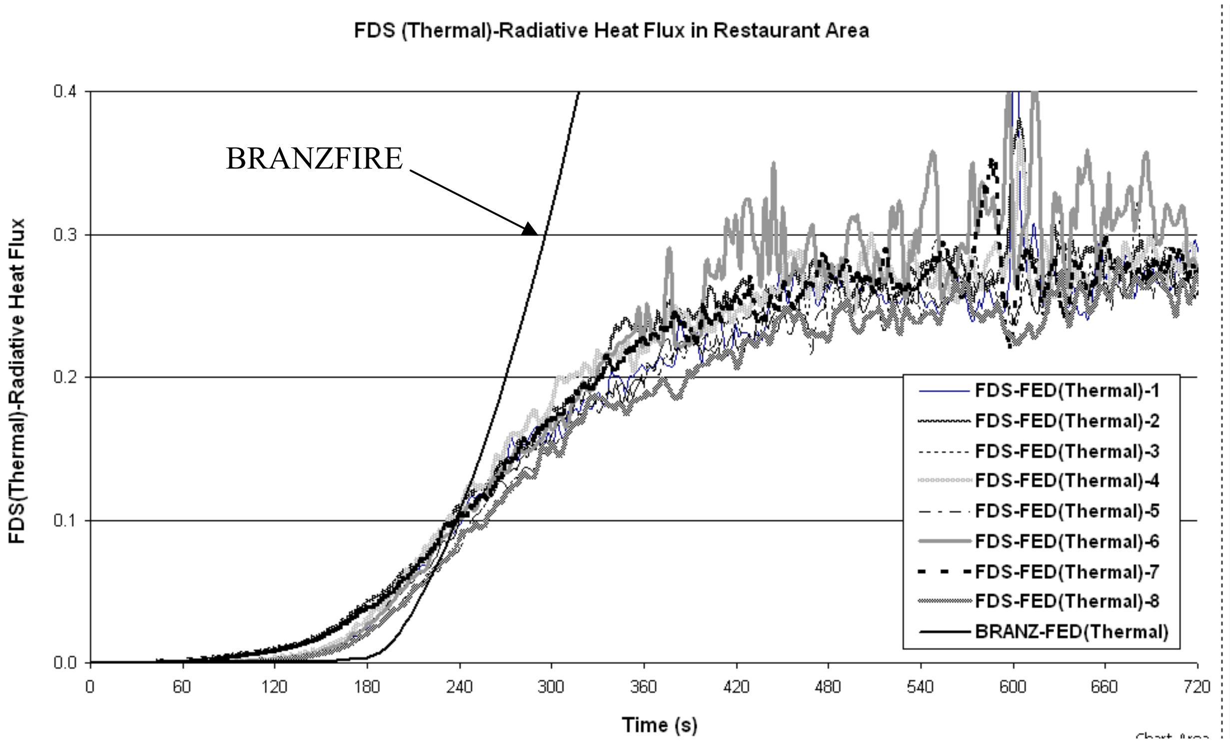
FED(CO) curves



FED thermal curves from gauge heat flux

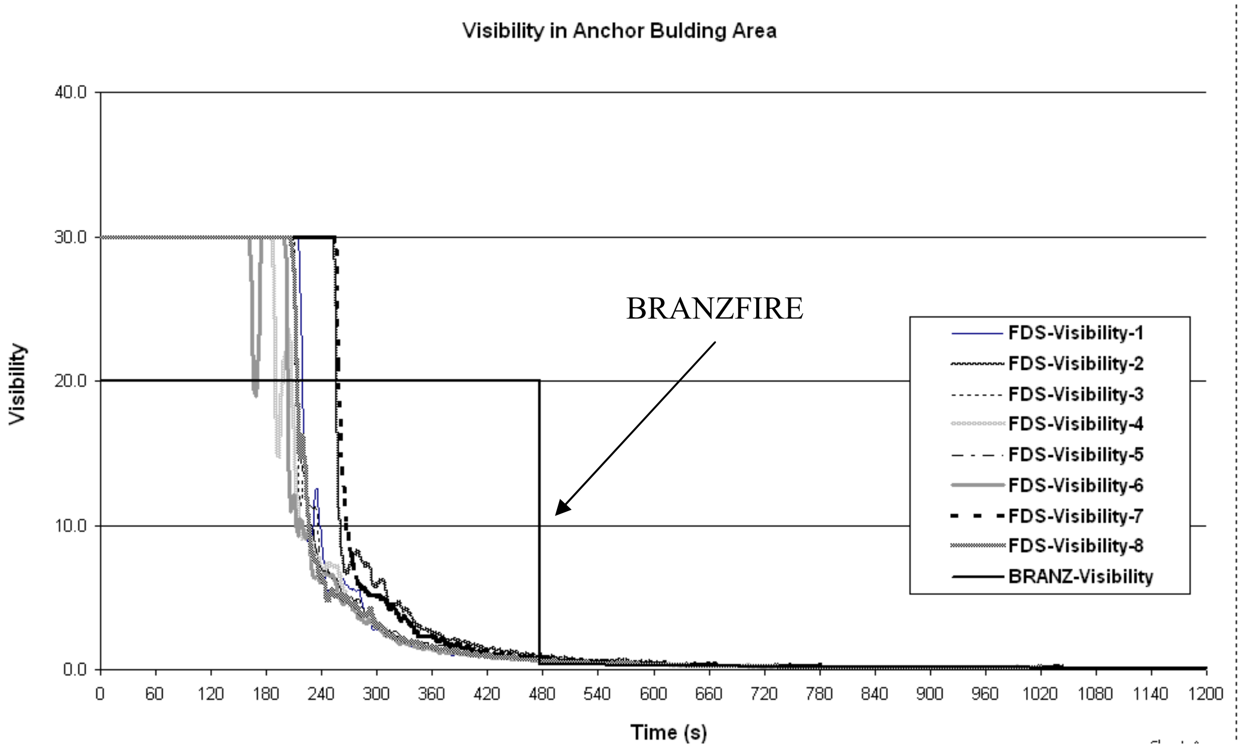


FED thermal curves from radiative heat flux

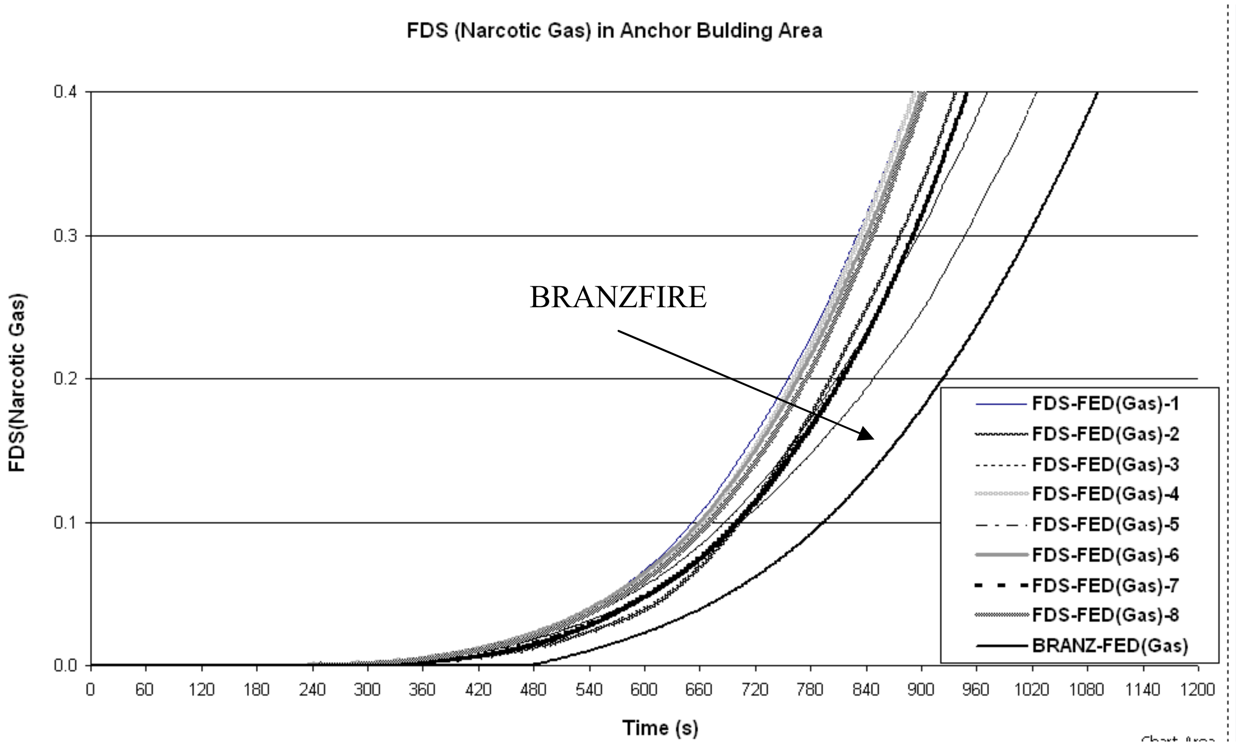


D3.11 Anchor building – 3 fire (not protected with sprinkler system)

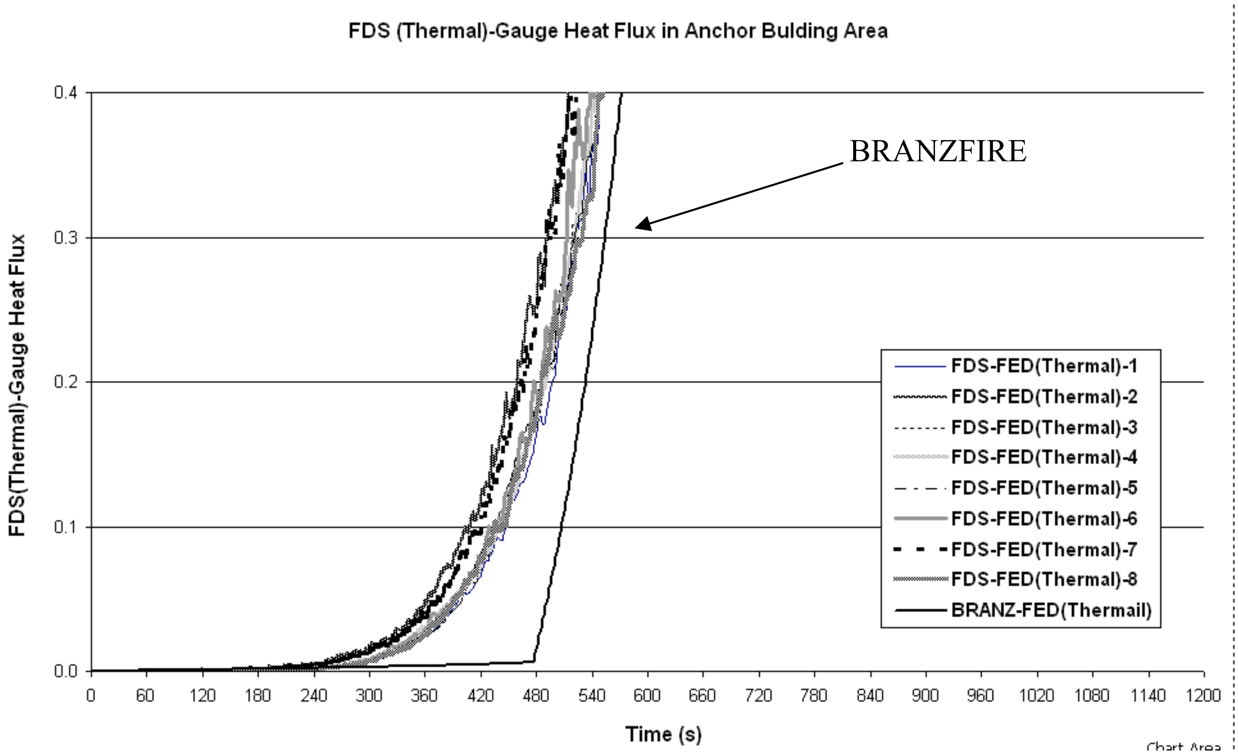
Visibility curves



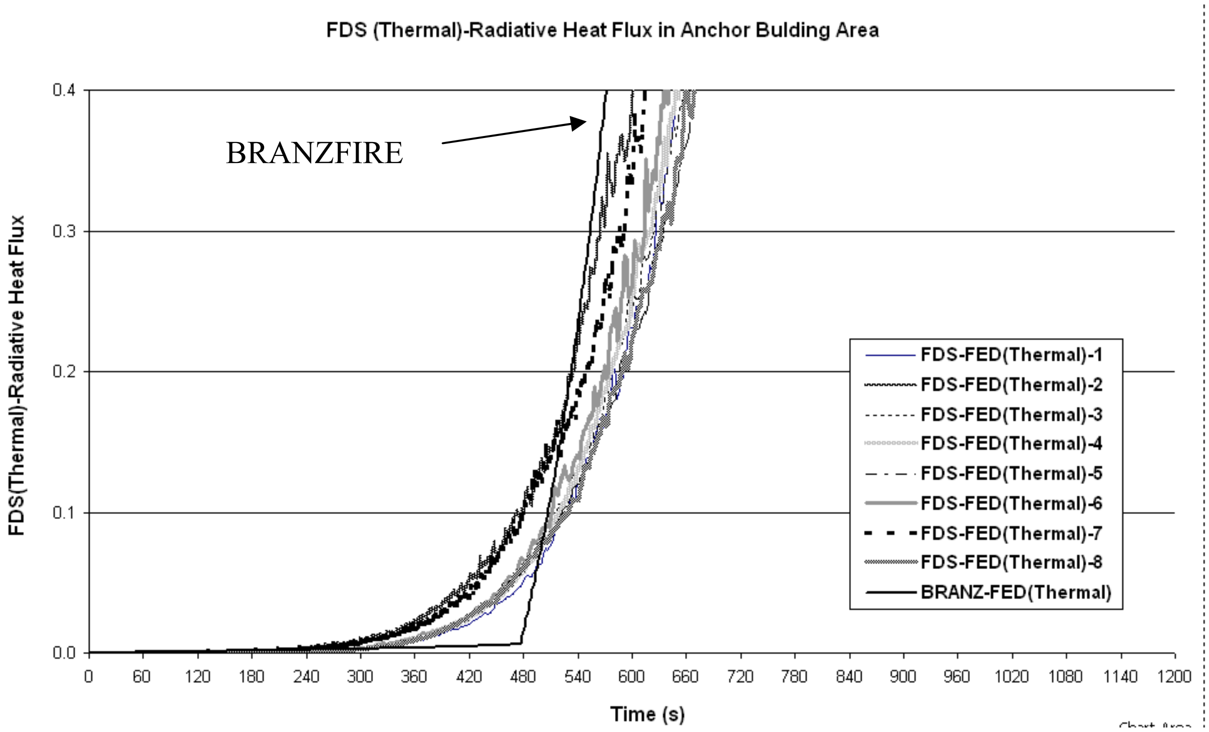
FED(CO) curves



FED thermal curves from gauge heat flux



FED thermal curves from radiative heat flux



Appendix E: External Wall Fire Resistance

Appendix E1: Extracted from NFPA5000 Table 7.2.1.1 [3]

Table 7.2.1.1 Fire Resistance Ratings for Type I Through Type V Construction (hr)

	Type I		Type II			Type III		Type IV	Type V	
	442	**332**	**222**	**111**	**000**	**211**	**200**	**2HH**	**111**	**000**
Exterior Bearing Walls[a]										
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0[b]	2	2	2	1	0[b]
Supporting one floor only	4	3	2	1	0[b]	2	2	2	1	0[b]
Supporting a roof only	4	3	1	1	0[b]	2	2	2	1	0[b]
Interior Bearing Walls										
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0	1	0	2	1	0
Supporting one floor only	3	2	2	1	0	1	0	1	1	0
Supporting roofs only	3	2	1	1	0	1	0	1	1	0
Columns										
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0	1	0	H	1	0
Supporting one floor only	3	2	2	1	0	1	0	H	1	0
Supporting roofs only	3	2	1	1	0	1	0	H	1	0
Beams, Girders, Trusses, and Arches										
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0	1	0	H	1	0
Supporting one floor only	2	2	2	1	0	1	0	H	1	0
Supporting roofs only	2	2	1	1	0	1	0	H	1	0
Floor-Ceiling Assemblies	2	2	2	1	0	1	0	H	1	0
Roof Ceiling Assemblies	2	1½	1	1	0	1	0	H	1	0
Interior Nonbearing Walls	0	0	0	0	0	0	0	0	0	0
Exterior Nonbearing Walls[c]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]

H: Heavy timber members *(see text for requirements)*.
[a]See 7.3.2.1.
[b]See Section 7.3.
[c]See 7.2.3.2.12, 7.2.4.2.3, and 7.2.5.6.8.

Appendix E2: Extracted from NFPA5000 Table 7.3.2.1 [3]

Table 7.3.2.1 Fire Resistance Ratings for Exterior Walls (hr)

Occupancy Classification	Horizontal Separation ft (m) 0 to 5 (0 to 1.5)	>5 to ≤10 (>1.5 to ≤3)	>10 to ≤30 (>3 to ≤9)	>30 (>9)	Opening Protectives
Assembly, educational, day care, health care, ambulatory health care, detention and correctional, residential, residential board and care, business, industrial, and storage occupancies with low hazard contents	1	1	0	0	See Table 7.3.5(a).
Mercantile and industrial and storage occupancies with ordinary hazard contents	2	1	0	0	See Table 7.3.5(b).
Industrial and storage occupancies with high hazard contents exceeding the maximum allowable quantities per control area as set forth in 34.1.3 and complying with Protection Level 1, Protection Level 2, or Protection Level 3	See Chapter 34 for minimum requirements.				
Industrial and storage occupancies with high hazard contents exceeding the maximum allowable quantities per control area as set forth in 34.1.3 and complying with Protection Level 4 or Protection Level 5	3	2	1	0	See Table 7.3.5(b).

Appendix E3: Extracted from C/AS1 Table 2.1 [2]

Table 2.1: Purpose Groups *(continued)*

Purpose group	Description of intended use of the building space	Some examples	Fire hazard category
WORKING, BUSINESS OR STORAGE ACTIVITIES			
WL	Spaces used for working, business or storage – low *fire load*.	Manufacturing, processing or storage of *non-combustible* materials, or materials having a slow heat release rate, cool stores, covered cattle yards, wineries, grading or storage or packing of horticultural products, wet meat processing.	1
		Banks, hairdressing shops, beauty parlours, personal or professional services, dental offices, laundry (self-service), medical offices, business or other offices, police stations (without detention quarters), radio stations, television studios (no audience), small tool and appliance rental and service, telephone exchanges, dry meat processing.	2
WM	Spaces used for working, business or storage – medium *fire load* and slow/medium/fast *fire* growth rates (e.g. <1 MW in 75 sec) **(Note 1)**.	Manufacturing and processing of *combustible* materials not otherwise listed, including bulk storage up to 3 m high (excluding *foamed plastics*).	3
WH	Spaces used for working, business or storage – high *fire load* and slow/medium/ fast *fire* growth rates (e.g. <1 MW in 75 sec) **(Note 1)**.	Chemical manufacturing or processing plants, distilleries, feed mills, flour mills, lacquer factories, mattress factories, rubber processing plants, spray painting operations, plastics manufacturing, bulk storage of *combustible* materials over 3 m high (excluding *foamed plastics*).	4
WF	Spaces used for working, business or storage – medium/ high *fire load* and ultra fast *fire* growth rates (e.g. >1 MW in 75 sec) **(Note 1)**.	Areas involving significant quantities of highly *combustible* and flammable or explosive materials which because of their inherent characteristics constitute a special *fire hazard*, including: bulk plants for flammable liquids or gases, bulk storage warehouses for flammable substances, bulk storage of *foamed plastics*.	4 (The critical factor in this *purpose group* is the rate of *fire* growth.)

Appendix E4: Extracted from C/AS1 Clause 7.3.12 [2]

Sprinklered firecells

7.3.12 For Methods 2 and 3 (but not Method 1), if a *firecell* is sprinklered:

a) The *unprotected area* in *external walls* determined from Table 7.2 may be doubled, or

b) The distance between the *external wall* and the *relevant boundary* may be reduced to 70% of the value required by Table 7.2, but not reduced to less than 1.0 m.

Appendix E5: Extracted from C/AS1 Table 7.2/6 [2]

Table 7.2/6: Method 2 – Enclosing Rectangles
Permitted Unprotected Areas in Unsprinklered Buildings

Rectangle height 9 m

Distance to relevant boundary (m)	Percentage permitted unprotected area																								
	Fire Hazard Category 1 Width of enclosing rectangle (m)								Fire Hazard Category 2 Width of enclosing rectangle (m)								Fire Hazard Category 3 and 4 Width of enclosing rectangle (m)								
	2	3	4	6	8	10	15	20	2	3	4	6	8	10	15	20	2	3	4	6	8	10	15	20	30
1.0	50	37	32	27	26	25	24	24	38	29	24	21	20	19	18	18	26	19	16	14	13	13	12	12	12
1.1	52	39	33	28	26	25	24	24	40	30	25	21	20	19	19	18	27	20	17	14	13	13	12	12	12
1.2	55	40	34	28	26	25	25	24	42	31	26	22	20	19	19	19	28	21	17	15	14	13	13	12	12
1.3	57	42	35	29	27	26	25	25	43	32	27	22	20	20	19	19	29	21	18	15	14	13	13	13	13
1.4	59	43	36	30	27	26	25	25	45	33	27	23	21	20	19	19	30	22	18	15	14	13	13	13	13
1.5	62	45	37	30	28	27	25	25	47	34	28	23	21	20	19	19	32	23	19	16	14	14	13	13	13
1.6	64	46	38	31	28	27	26	25	49	35	29	24	22	21	20	19	33	24	20	16	15	14	13	13	13
1.7	67	48	39	32	29	27	26	26	51	37	30	24	22	21	20	20	34	25	20	16	15	14	13	13	13
1.8	69	50	40	33	29	28	26	26	53	38	31	25	22	21	20	20	36	25	21	17	15	14	14	13	13
1.9	72	51	42	33	30	28	27	26	55	39	32	25	23	22	20	20	37	26	21	17	15	14	14	13	13
2.0	75	53	43	34	30	29	27	26	57	40	33	26	23	22	21	20	38	27	22	17	16	15	14	14	13
2.1	77	55	44	35	31	29	27	27	59	42	34	27	24	22	21	20	40	28	23	18	16	15	14	14	14
2.2	80	57	46	36	32	30	28	27	61	43	35	27	24	23	21	21	41	29	23	18	16	15	14	14	14
2.3	83	58	47	37	32	30	28	27	63	45	36	28	25	23	21	21	43	30	24	19	17	15	14	14	14
2.4	86	60	48	37	33	31	28	28	66	46	37	29	25	23	22	21	44	31	25	19	17	16	15	14	14
2.5	89	62	50	38	34	31	29	28	68	48	38	29	26	24	22	21	46	32	26	20	17	16	15	14	14
2.6	92	64	51	39	34	32	29	28	70	49	39	30	26	24	22	22	47	33	26	20	18	16	15	15	14
2.7	95	66	53	40	35	32	30	29	73	51	40	31	27	25	23	22	49	34	27	21	18	17	15	15	15
2.8	98	68	54	41	36	33	30	29	75	52	41	31	27	25	23	22	50	35	28	21	18	17	15	15	15
2.9	100	71	56	42	36	33	31	30	77	54	43	32	28	26	23	23	52	36	29	22	19	17	16	15	15
3.0		73	57	43	37	34	31	30	80	55	44	33	28	26	24	23	54	37	29	22	19	18	16	15	15
4.0		97	75	55	46	41	36	34	100	74	57	42	35	31	27	26	73	50	39	28	24	21	18	18	17
5.0		100	97	69	56	49	42	39		96	74	53	43	38	32	30	95	64	50	35	29	25	21	20	19
6.0			100	86	69	59	49	45		100	93	65	52	45	37	34	100	82	62	44	35	30	25	23	21
7.0				100	83	71	56	51			100	80	63	54	43	39		100	77	54	43	36	29	26	24
8.0					99	84	65	58				96	76	64	50	44			94	65	51	43	33	30	27
9.0					100	98	75	65				100	89	75	57	50			100	77	60	50	38	33	30
10.0						100	86	73					100	87	65	56				91	70	58	44	38	33
11.0							97	82						100	74	63				100	81	67	50	42	36
12.0							100	92							84	70					94	77	57	47	40
13.0								100							94	78					100	88	64	53	43
14.0															100	87						99	71	58	48
16.0																100						100	88	71	56
18.0																							100	85	66
19.9																								100	100

Notes:

1. Percentage *unprotected areas* may be linearly interpolated between enclosing rectangle widths and between distances to the *relative boundary*.
2. For enclosing rectangle widths greater than the maximum values given in the table, an enclosing rectangle width of 20 m for *FHC* 1 and 2 or 30 m for *FHC* 3 and 4 may be used.